WORKS IN IRON

BY

ANDREW HANDYSIDE & Co.,

BRITANNIA IRON WORKS, DERBY, AND 32, WALBROOK, LONDON.

SECOND EDITION.

(Without Photographs.)

London:

E. & F. N. SPON, 48, CHARING CROSS.

1868.

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Introduction.

THIS book is published as one useful for reference to all those at home or abroad who may be interested in engineering and other ironwork, of which we have here endeavoured to give in a convenient form the most modern examples. The various works and classes of machinery described in these pages having been manufactured by ourselves, the information given may be relied on as a correct guide in forming estimates of cost. The book treats of three distinct classes of work: Firstly, Constructive Ironwork, such as roofs, buildings, and bridges; Secondly, Steam Engines, Machinery, and Foundry Work; and Thirdly, Ironwork of a specially ornamental character.

THE Britannia Iron Works, Derby, were established at the beginning of the present century, at first as an Iron Foundry chiefly, and were soon known for the superior quality of what were called "Derby castings." This arose partly from the local advantages of good iron and good moulding sand, and partly from the special skill of the moulders who were settled in the town. This superiority, it is believed, still exists, and is more fully spoken of at page 3, under the head of "Quality of Iron."

Steam engines and machinery of various kinds for collieries, factories, breweries, &c., are manufactured at the Britannia Iron Works, and also upon a large scale constructive ironwork—bridges, iron buildings, roofs, and ornamental structures, a detailed account of which will be found in these pages.

At the Universal Exhibition in 1851 a medal was awarded for our "Iron Castings," and at the International Exhibition in 1862 we again received a medal for "Iron Castings," and a second one for Machinery shown by us.

The Britannia Iron Works are situated on the River Derwent, by means of which there is direct communication with the leading canals in the country. The goods station of the Midland Railway is within a few hundred yards, so that there are easy means of transit to the ports and to all parts of the country. The carriage rates of both the Railway and Canal Companies are very advantageous, particularly with London, Liverpool, Bristol, and Hull. We have endeavoured to describe in this book all the different classes of work we execute, but as these are diverse in character, and subject to constant changes, it is not easy to give exact prices, although we do so wherever it is possible. Estimates, however, are always willingly furnished, and if they be required, designs can be prepared with all proper engineering skill. For effecting delivery in or shipment from London, our office there affords every facility.

The current price of iron at a particular time, or the quantity of work ordered, may of course somewhat modify the prices we quote. These in all cases include delivery at the ports we have mentioned, or to any railway station within 120 miles of Derby.

Andrew Handyside & Co.

1868.

THE QUALITY OF IRON.

AS a correct knowledge of the quality of material is essential to a proper estimate of the value of work, the due consideration of these pages will be assisted by the following particulars.

The most careful experiments as to the strength of iron have been made by Mr. Fairbairn, of Manchester, and the information thus obtained by him has now for some years been used by engineers as accurate and trustworthy. For proving the strength and toughness of cast iron, he adopted the girder test of a bar one inch square, placed on bearings four feet six inches apart, and loaded in the middle till broken. After trying almost all the varieties of iron in Great Britain, he found that the breaking weight varied from about 310 lbs. to 580 lbs., and that the range of deflection of the bars before breaking was from one to two inches. This furnishes a convenient scale for measuring quality.

In melting iron it is usual to improve the metal by mixing different kinds together, but this is too often not done to a large enough extent. The iron produced in certain localities, and manufactured into heavy columns, girders, and other castings required at low prices, is notably deficient, and would stand much less than 400 lbs. by Fairbairn's test. Although a slight saving in price per ton can be effected by using such material, it involves heavier forms, which raise the total cost to at least that of the superior iron, while the freight is obviously in excess of the better and lighter material.

For cast-iron work subject to transverse strains, tough iron is especially necessary, and it is now demanded by the best engineers, who use an improved test bar, two inches deep, one inch wide, and three feet between bearings. This is submitted to a breaking weight of from 25 cwt. to 30 cwt., thereby precluding the use of a large quantity of the cheap iron that sometimes is sold when this test is not exacted. The pig-iron used at the Britannia Iron Works is obtained chiefly from the adjacent smelting furnaces in the county, and from Scotch furnaces of high repute, and is

the best obtainable in Great Britain. In a report published in 1854, of experiments at Woolwich, ordered by the House of Commons for ascertaining the strength of different irons for use in cast-iron ordnance, out of fifty kinds tried in tension, torsion, compression, and in transverse strain, the irons from the furnaces above referred to stood highest, and as compared with the lowest were about as thirteen to five. By continued and repeated experiments made by And^{w}. Handyside & Co. at these works with the meltings that take place twice a day, it has been found that the castings will take as a breaking weight 450 lbs. to 612 lbs. on the one inch bar. As an instance of this may be mentioned the columns made there for Mr. Spurgeon's "Tabernacle," the test bars of which broke with 613 lbs. For some iron work lately sent by And^{w}. Handyside & Co. to India, samples were tried at Mr. Kirkaldy's testing apparatus in London, and the three feet bars broke with 31 to 41 cwt. of dead weight. These facts are given to show—what may not be generally known—that very great variety exists in the quality of cast-iron work as now made. A minimum of 450 lbs. of Fairbairn's test, or 24 cwt. on the three feet bar, should in all cases be demanded, and for any but compression loads higher standards are advisable. When castings have to be sent abroad, where it is difficult to replace them if broken, cheap iron is false economy.

With regard to wrought iron, although its varieties of quality and strength are more definitely understood, large quantities of a very bad kind are sometimes used for cheap girders, and even for boilers. The Board of Trade has a rule which is now generally adopted—that the proof load of any structure shall not exceed five tons in tensile strain per square inch. But to allow a sufficient margin for safety against sudden shocks and other accidents, engineers generally demand iron that will stand twenty to twenty-three tons. Now much of the inferior iron just referred to will break with seventeen tons, is besides variable in its strength, and possesses little elasticity.

The appearance of a fracture in wrought iron affords a fair indication of quality—bad iron being generally crystalline, and good iron fibrous. The quality of wrought iron used at the Britannia Iron Works is a matter to which *the most careful attention is always given.* And^{w}. Handyside & Co. will, where required, specify strains which they are prepared to guarantee, in both cast and wrought-iron work.

BRIDGES.

IN no branch of engineering has greater progress been made during the last twenty years than in the construction of iron bridges. Examples of those made from designs by the best engineers are given here with an approximate estimate of cost.

PIERS.

THE piers form a special part of the construction of bridges, and with other sub-aqueous work, often involve a large proportion of the expense. Where stone is used for piers, great facilities in construction have been given of late years by the use of iron caissons, instead of the old pile coffer dams, the latter causing, as in the case of the present London Bridge, an immense expenditure of time and money, that can now to a great extent be avoided. These caissons are made of wrought or cast iron, either curved or rectangular, and are loaded with dead weight, while the soil is removed inside, and the water pumped out. They are thus forced into the bed of the river till they reach a stratum firm enough to bear the piers; concrete, stone, or brick, can then be conveniently and quickly built up to the required level. This is the system adopted with the new bridges over the Thames at Blackfriars and Battersea, and a large portion of the Thames Embankment has been built below the level of the water, under protection of these caissons, on the river or outer side. This system is particularly applicable in such cases as that of the Thames, at London, on account of the presence of the London clay, which, when reached by the bottom of the caisson, permits the latter to be pumped clear of the water, and is sufficiently solid for the erection of the piers.

The iron casing having served its purpose can either be removed or left as a shell to enclose and preserve the pier from damage. With cylindrical piers this latter plan is generally adopted, and the iron may be made of such thickness as to add considerably to the strength of the piers, giving the bridge at the same time the appearance of

being supported on iron pillars. In some cases the cylinders serve as columns, and themselves support the entire weight of the superstructure. The foundations of the Queensland Bridge, shown in engraving, and described on page 14, partly illustrate both these methods. The iron cylinders are generally made of metal from one inch to one and a half in. thick, and each length is accurately faced at the abutting ends to ensure a perfect joint. The price of these is about £8 per ton. Where the cylinders are so large that it is necessary for convenience in shipment, or for other reasons, that they should be made in small pieces, each circle is formed of segments, which have to be planed on their radial flanges, and in these cases the cost would be about £1 per ton extra. But this labour of planing may be avoided sometimes by casting the complete circle at once with "dividing pieces," so that the founder can separate the segments when cold. They can afterwards be bolted together in their original places with great exactitude. But when it is required that the segments shall be interchangeable, in case of breakage, this plan can hardly be adopted, and the cost of planing must be incurred.

While cylinders as just described are most common for the largest bridges, smaller bridges often rest on piers formed of iron piles. There are many different forms of these, and no fixed rule can be made for general application, as everything depends upon the nature of the river bed, the strength of the water current, and other local peculiarities. Where the flow of water is strong, it is best to offer as small an obstruction to its passage as possible, but it is necessary also to consider the grip or holding power that exists in the bed of the river, and these circumstances together generally determine whether the piles shall be hollow or solid. Hollow piles are parallel tubes of from one to two feet diameter, made in convenient lengths of cast or wrought iron, joined by bolts at their flanges. Various ways have been tried of fixing pile piers. In some cases the air has been exhausted in the tube, and the consequent forcing up of the soil has allowed of easy insertion. In other cases a pressure of water forced into the tube has driven the soil away from below, and allowed the pile to descend; and sometimes the piles are driven in by a falling weight. The method usually adopted, however, is to use piles armed at the end with a screw, and these piles are turned round by a capstan, and thus screwed into the ground like augers. The shape of the screw blade depends

entirely on circumstances, and a hard and soft gravel, sand, or clay, demand different kinds of blades and pitch of thread. So much uncertainty often exists as to the soil, that where possible it is well to insert one pile before determining absolutely on the shape of screw, or at any rate to take very accurate borings. In the construction of screws, and in the machinery for their insertion, Andw Handyside & Co have made several improvements, which have been suggested by actual practice. Cast-iron hollow piles with screws cost about £8 to £9 per ton. After hollow piles have been fixed they may be filled with concrete.

Some engineers prefer to use solid wrought-iron piles, and this can be done to advantage in many cases. Such piles are generally from four inches to nine inches diameter, and can be made in considerable lengths. If needed, these are joined by bolts and flanges, or by couplings, while the screw is of cast iron, made separately and attached to the bottom of the pile. The price of piles of this description averages from £13 to £17 per ton.

The obstruction offered by piers to the stream sometimes causes the flow of water to "scour" round the foundations, and loosen and wash away the soil from below. Care should be taken to watch against this when a bridge is first erected, and, if necessary, heavy stones may be deposited so as to resist the current. Where a river is subject to floods bringing down heavy *débris*, fender piles of timber are sometimes fixed to protect the piers from damage.

The cylinders or piles forming a pier are generally braced together by diagonal and horizontal ties and struts, the former of wrought iron and the latter of cast iron, or of wrought L or T iron rivetted together, so as to offer a rigid resistance to a compressive strain.

GIRDERS.

MANY different considerations may affect the choice of girders, and the manner of their arrangement, but there are certain points in their manufacture which are common to all, and which require notice here.

The *quality of the iron* (referred to generally at page 3). As a rule, plates are about 10 per cent. weaker in tension than bars rolled from the same iron. In the smaller and simpler plate girders for sustaining moderate weights, and subject to little or no moving load, iron of ordinary strength is sufficient, a breaking strain of nineteen tons per square inch for the plates and twenty-one tons for the angle and other bars being as much as is necessary. Where no specified quality is demanded, engineers cannot reckon on obtaining iron of greater capacity than the above, and they generally demand therefore for the better class of girders a higher standard of value, twenty tons for plates and twenty-two tons for bars being the tests now generally adopted. Anything beyond these, such as tests of twenty-three or twenty-four tons, implies very high quality, and involves a proportionate additional cost, which is seldom incurred except in those girders described hereafter, in which the character of the work is altogether of a superior kind. It is of the greatest importance therefore in estimating the real cost of girders to know by whom the iron will be supplied, and its quality.

The *character of the workmanship.* This of course determines the ultimate value of any structure, as the same design may be carried out in different ways. In a rivetted girder it is desirable that the various parts be so put together, that when finished they shall resemble and possess as nearly as possible all the powers of a beam constructed of one piece of iron. On this the strength of the entire structure depends, and it is necessary therefore that the work be accurately fitted together, and that each rivet shall completely fill the hole made to receive it. The latter is best effected by the careful use of a rivetting machine, which with one stroke presses the heated rivet and completely fills with it every interstice in the iron which it enters. This is fully shown when a rivet has to be removed. If it has been hammered in by hand, it is easily driven out when the head is cut off, but if it has been machine-rivetted, it is generally necessary to *drill* it out, so completely has it become part of the iron into which it was forced. In the "Warren" and other girders of the same character described further on, the work cannot be properly done except by the most accurate methods; and pins must be turned and holes drilled to gauges measuring

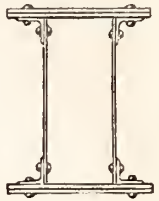
to the *hundredth part of an inch*. In these, as in rivetted girders, the object desired is a structure which shall resemble one piece of iron. If this result be not obtained, the girder must when loaded necessarily bend to an undue extent, and, after this deflection, will not be elastic enough to resume its original form when the load is removed, thus showing more *permanent set* than would occur in a girder properly made.

Girders are sometimes constructed to carry their load on the top; in other cases the load rests upon the bottom flanges, the girder thus acting as a parapet. In the former case the crossbeams which carry the floor unite the girders at the top; in the latter case it is necessary to strengthen the girders so as to stiffen the top flanges, and retain them in position. Brackets fastened to the piers help the girders to resist a lateral strain. In some cases, where there is sufficient head room to permit it, this lateral strength is given by light beams placed across the bridge, joining the upper flanges of the different girders together, as in the Railway Bridge over the Thames at Blackfriars.

The depth of a girder in proportion to its length, varies from one-tenth to one-fifteenth for single girders, and from one-twelfth to one-twentieth for continuous ones, and is determined within these limits as circumstances may make the application of material convenient or economical, the quantity of iron increasing as the correct proportion is departed from. In some cases where head room is valuable and it is impossible to use a deep girder, the necessary strength is given by heavier sections of iron, but the weight of iron required in a girder of insufficient depth is much greater than in one of equal strength where the proper proportions are observed; and, moreover, deflection begins sooner and increases more rapidly. On the other hand, where a girder is made excessively deep, a greater weight of material is necessary in the web or parts that connect the top and bottom members.

Of the many kinds that are made, the plate girder is the most simple, and up to a certain size, the most economical. It is rigid and durable, easy to make, and is the most appropriate for small spans. Those of small size

are made with a single web plate, connecting the upper and lower flanges, and strengthened where necessary by vertical stays and "gussets." Where great rigidity and strength are needed, two web plates are sometimes employed, thus enclosing a space, and making what is called a box or tubular girder. This enables wider flanges to be used, and makes a much stronger beam. It is, however, necessary that the inside of the girder shall be spacious enough to give access to the painter's brush, for it is often not easy to paint the inside of box girders, and unpainted they are liable to rust and consequent deterioration.



Sufficient strength is given to plate and box girders by the addition of plates to the flanges, in number increasing towards the centre, as needed to take the tensile and compressive strains, and this is necessary for all but very short girders. Where, however, it is done to excess so as to save depth, it requires, as before stated, a more than proportionate weight of iron. In a series of successive spans, additional strength may be obtained by joining the girders together at the ends, thus making a continuous girder. Girders thus united allow of increased length of span, or of a diminution in the depth of the girder itself, as compared with girders placed singly. The value of plate and box girders is from £13 to £16 per ton.

As a substitute for very small rivetted girders, rolled beams have been introduced during the last few years, and have been used in large numbers. For small spans, for carrying arched brick floors, and for acting as cross bearers between larger girders, they are simple and useful. They are made from 5 ins. to 20 ins. in depth, and cost from £10 to £14 per ton, the smallest and narrowest sections being the cheapest. Any extra work in attaching them to other ironwork involves extra cost.

Beyond fifteen feet span, trellis or lattice girders can be used as an alternative to those just described, but up to thirty or forty feet there is no economical advantage gained, the plate girder having superior strength and stiffness. Where, however, a moderate load only has to be carried, the open lattice-work has generally a better appearance. Beyond eighty feet span, plate girders with a single web are seldom used, and other forms are necessary

for the proper and economical application of material. Lattice or open-work girders of every kind may be generally said to involve a nicer appreciation of the strains produced by the load, and of the form of structure necessary to endure them, than in plate girders.

The ordinary lattice girder has its top and bottom members composed of plates and angle irons, much in the

same way as a plate girder. At regular distances apart, vertical struts unite the two flanges, and a series of diagonal bars crossing each other fill up the intermediate spaces. In some cases plain flat iron is used for this purpose; in others T and L irons replace or strengthen the bars that should possess the greatest rigidity. Girders of this description are a little dearer than those formed of plates, and cost from £14 to £16 per ton. The girders of the bridge over the Avon, illustrated and described at page 17, are of this kind.

A still closer adherence to the forms best adapted for the strains occurring in its different parts is found in the so-called "Warren" girder, although many modifications have been made since the adoption of the design that first bore the name. As seen in diagram the diagonals do not cross or interlace, but form a succession of single triangles.

These diagonals take alternate tensile and compressive strains from the centre of the girder to the piers. The principle upon which these girders are constructed requires that the load shall be applied on the upper flange, but with a slightly altered form and increased strength the weight may be carried on the lower flange. As so much lightness is given to this form of girder, and as the whole safety of the structure depends upon the strength of every part, a high quality of

iron and extreme accuracy of workmanship are demanded by engineers. In a number of bridges of this kind lately manufactured for Indian Railways by Andw. Handyside & Co., from the designs of Mr. Rendel, the struts and ties of the girders were made of iron equal to a breaking strain of twenty-four tons per square inch. These were connected by turned steel pins to the top and bottom flanges of the girders, which were put together with such accuracy that in twenty spans of eighty feet each any of the corresponding struts and ties were interchangeable. Where bridges have to be conveyed by ship, and carried across country, the smallness of the pieces into which a "Warren" girder may be divided renders their transport comparatively easy. From £16 to £19 per ton is the general price at which these can be made, the smaller weight of material employed counterbalancing the high rate per ton.

The trussed bridge described at page 14 might almost be termed a double "Warren," as the same principle is involved, though with double or compound triangles. In this case less dependence has to be placed on any single

strut or tie. Many other designs are adopted by engineers in the construction of trussed girders, but these are generally modifications of the forms that have been mentioned here, the lightness of the structures in all cases demanding good

material and workmanship, and the price being estimated accordingly. The two diagrams are examples of these.

STEEL BRIDGES.

THE use of Bessemer and other steel has largely increased during the last few years, but it has not as yet been employed to any considerable extent in the construction of bridges. As a material for girders of large span, steel possesses some advantages over iron, which will doubtless lead to its further adoption, but at present there are

many differences of opinion among engineers as to the expediency of using it. Under most of the strains to which steel may be subjected it possesses a strength about double that of iron, and its use allows therefore a proportionate lightness of girder. This again permits a consequent reduction in the strength of material necessary to maintain the structure itself. It is essential, however, that its high quality should be equable and in all cases to be depended on, and engineers at present feel uncertain as to their always obtaining this uniformity, and they consider it therefore necessary to test a larger proportion of the separate parts of steel than of iron girders. The continual alterations and improvements that have taken place in the manufacture of steel renders it probable that many present objections to its adoption may be removed, and its use considerably extended. In girders of moderate size the use of steel involves plates and bars extremely light and thin, and in small bridges the weight of the girders would thus bear so small a proportion to the moving load as to permit undue vibration of the structure. In large bridges this objection would not arise, and it is in these that steel will probably be oftenest adopted. The limit of span which has hitherto been permitted in iron girders is largely increased in the lighter steel girders. Although the different parts of a steel girder may possess a first strength equal to double the same of iron, yet the natural deterioration by rust and wear (though somewhat less in steel than in iron) tells in greater proportion on the slighter substance of steel. But this drawback to its use is not of so much consequence in girders of large size, where steel of considerable thickness may be used. For the tension members of girders, and for the chain links of suspension bridges, steel has been employed to advantage in structures which are mainly of iron, and now that steel is being rolled into so many of the forms which are usual in iron, it is not unlikely that solid piles or columns for sustaining bridge girders may be made of steel. For small bridges, however, where iron piles of small diameter would be used, it would be impossible still further to reduce the diameter so as to effect any saving by using steel. For bolts and pins where a very severe shearing strain has to be resisted, steel is most judiciously used. It, however, is not quite so easily worked as iron, and to the cost of material, therefore, must be added a larger price for the workmanship. At the present time the cost per ton of steel girders is about double the price of iron girders.

EXAMPLES OF BRIDGES.

RAILWAY BRIDGE, QUEENSLAND, AUSTRALIA.

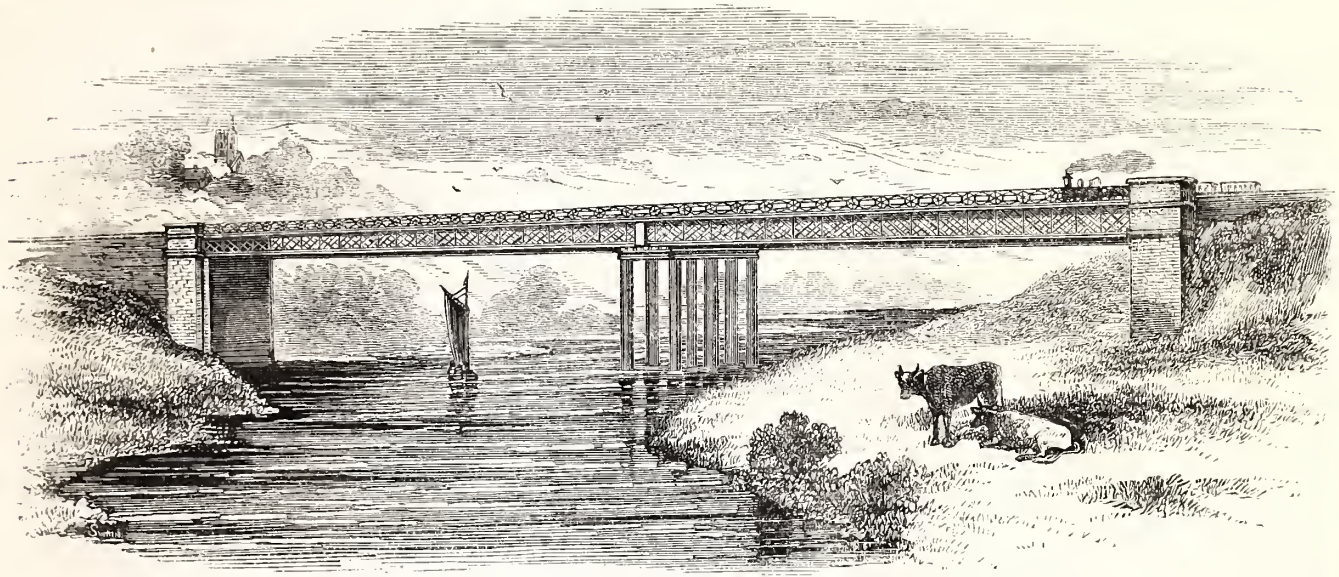
The bridge shown in the engraving was manufactured by Andw. Handyside & Co., in 1865, for the Queensland Railway in Eastern Australia. It was designed by Sir Charles Fox & Son, the English engineers of the Company, to cross the River Bremer at a part where the stream is 450 feet wide; it consists of three spans of 150 feet each, which carry a single line of railway, and a carriage road and footway. The piers are slightly on the

skew, and are formed of cast-iron cylinders, six feet six ins. in diameter, in lengths of six feet, the circles being made in three segments, and the metal $1\frac{1}{8}$ ins. thick. These cylinders are placed twenty-five feet apart, and are united by horizontal and diagonal bracing. The lower portion of the cylinders, where exposed to a constant flow of water, are filled in with brickwork, and the solid foundation thus constructed sustains the iron columns which carry the superstructure.

The main girders are ten feet nine inches deep, having their top members formed of cast-iron tubes, twelve inches diameter, made in convenient lengths, and increasing in thickness from the ends. The bottom flange of each girder is formed of parallel links, six inches wide, varying from four to twelve in number, and capable of taking a heavy tensile strain. These links are united at the ends by turned steel pins, and as they were to be interchangeable in the bridge, the greatest accuracy was needed to ensure the erection in place. The diagonal struts are framed of flat bars placed twelve inches apart, so as to grasp at the upper end the cast-iron horizontal tube, and are connected to the bottom flange by the steel pins which unite the links. The struts are strengthened by angle irons rivetted inside the bars, and by distance pieces placed at intervals, so as to give sufficient rigidity for the compressive strain. The diagonal ties are nine inches broad, formed of bars thickened at the ends by plates so as to give a greater bearing surface for the shear of the pins; the sections of both struts and ties varying in strength according to their position in the girder. The ends of the trusses are firmly connected to the tops of the piers, and the shore ends of the side spans rest on rollers. The contraction and expansion of the truss in the centre is allowed for by the yielding of the piers, which are about fifty or sixty feet high. Lattice girders one foot six ins. deep, carry the roadway, and overhang the top of the main girders five feet nine ins., acting as cantilevers to carry a footway. A neat hand-railing of wrought iron runs along both sides of the bridge, and there is also a railing to divide the railway from the ordinary traffic. The ironwork was shipped from England in pieces of convenient size, which were readily and quickly put together and erected in place. The bridge contains 217 tons of cast iron and 277 tons of wrought iron. A full description with detailed engravings appeared in the "Engineer" of October 12th, 1866.

RAILWAY BRIDGE, WHITNEY, HEREFORDSHIRE.

The railway bridge over the river Wye, at Whitney, in Herefordshire, was erected by Andw. Handyside and Co. in 1863, and is 328 feet long. In this case the piers are formed of hollow wrought-iron columns of a peculiar section, strongly framed together, attached at the lower ends to piles screwed into the river bed to a depth of from twelve to twenty feet. There are three main spans of eighty feet each, and two shore ends of forty-four feet each, the latter resting on stone piers. The long girders are eight feet deep, and of the



BRIDGE OVER THE AVON, NEAR BATH.

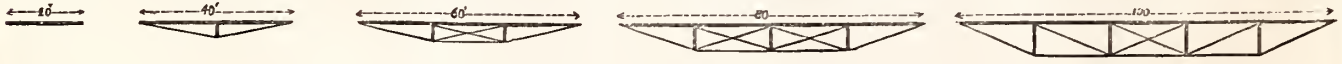
lattice form, shown in the sketch, the top and bottom flanges being of channel irons, eight inches deep, and covered by plates fourteen inches wide. The diagonal ties are formed of flat bars, the struts of double T iron, and there is a strong horizontal bracing of tie rods tightly adjusted by screw couplings. The roadway is of timber thirteen feet wide carried on joists 9 ins. × 6 ins., and there is a considerable depth of ballast. This bridge was tested by a train of locomotives standing and moving upon it, and by a heavy running load.

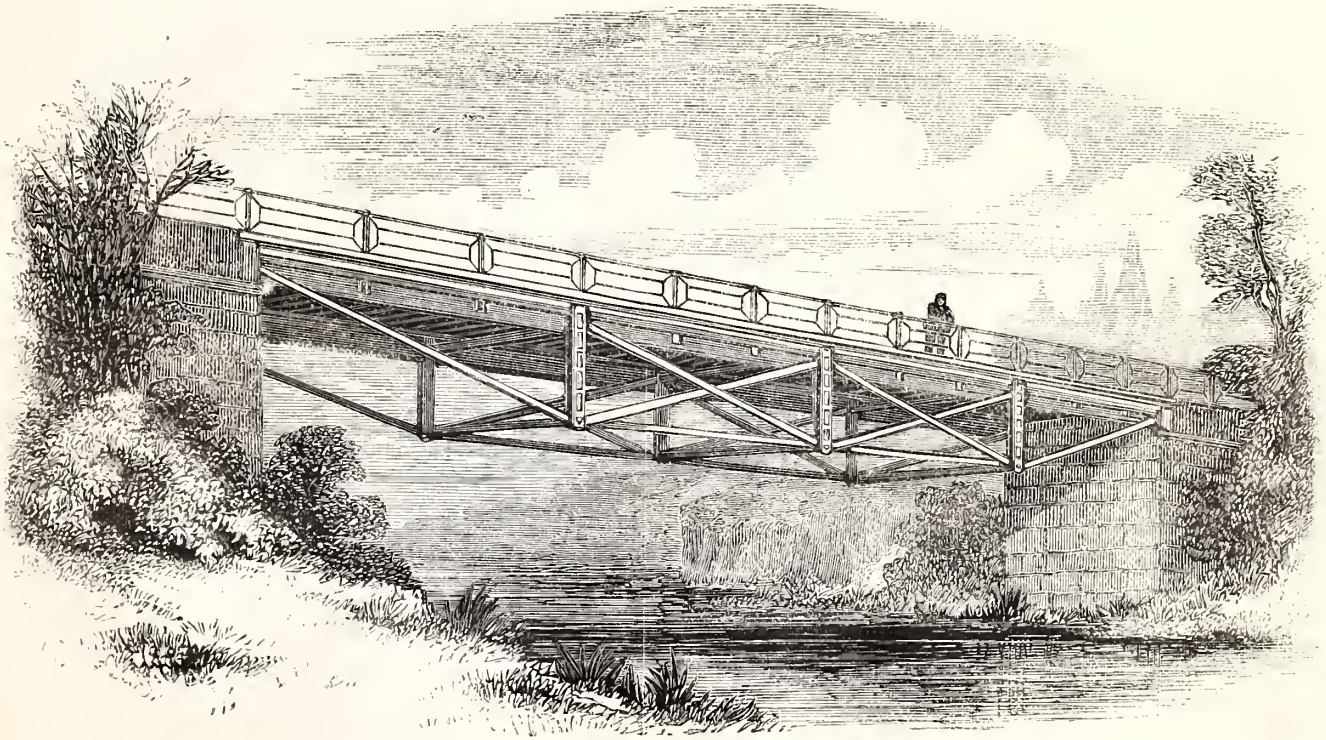
The bridge shown on the preceding page is one of six lattice bridges recently erected over the river Avon, near Bath, by Andw. Handyside & Co., for the Midland Railway Company, from designs by the Company's engineer. The pier in centre of bridge is formed of ten screw piles standing in a double row, and braced together at each nine feet of height. The piles are of cast iron, two feet diameter, filled with concrete, and have screw blades four feet three inches diameter and twelve inches pitch. The piles are united at the top by a cast-iron girder, upon which are bolted the corbels to carry the superstructure. Each span is composed of six main lattice girders, eighty-two feet long and six feet deep, having their top and bottom flanges formed of web plates, twelve inches deep, joined by strong angle irons to plates one foot six inches wide. The diagonals are flat bars very close together, and vertical channel iron bars form struts about eight feet apart. On the top of the girders are timber beams and planking to form the floor of the bridge, and the rail level is about thirty-five feet above the water. The cast iron weighs 110 tons, and the wrought iron 200 tons.

The other five bridges referred to above are in spans ranging as high as 120 feet, some of them carrying two lines of rails, and the fifth bridge four lines. Three of these bridges differ from the bridge above described in having the roadway attached to the lower flange of girder.

HANDYSIDE'S COLONIAL BRIDGE.

THE form of bridge shown on the next page was designed for new colonies and foreign countries, where transport is difficult and skilled labour rare and expensive. It is so arranged that there shall be no pieces of excessive size or weight, and that the mode of erection shall be simple and speedy, without any rivetting. The diagrams show five different spans, and the engraving gives an example of one span of eighty feet. The arrangement of details





HANDYSIDE'S COLONIAL BRIDGE.
D 2

is the same in all cases, the sizes and weights alone differing. It is assumed that each bridge shall have a clear roadway thirteen feet wide, and shall be capable of sustaining a moving load of 100 lbs. per square foot, or half a ton per foot run. The bridge can rest on iron piles, stone piers, rock, or timber, as may be most convenient, and it is specially to be noted that as the bridge is sent complete from England, it needs no fastening to its supports, but only requires a level and firm surface on which to rest. The bridge shown in engraving consists of two main trusses twelve feet apart, each truss made up of four wrought-iron girders planed truly at the ends so that they may abut fairly on the cast-iron struts to which they are bolted. The struts are also planed and trussed with strong flat bars connected at the ends by accurately turned pins. Cross girders on the main trusses carry the roadway, and have placed on their outer ends an iron railing. The main trusses are all strongly braced together transversely by cast struts and wrought-iron rods, which complete the rigidity and firmness of the structure.

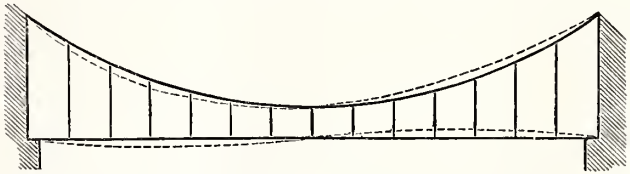
Great facilities are given for shipment, as will be seen by the sizes and weights detailed below, and each bridge is completely fitted together in England, and marked for re-erection abroad, where it is only necessary to insert and screw up the bolts. No rivetting is required, and a simple drawing is sent with each bridge to serve as a key to the numbers and marks on the different pieces. The best material and the most accurate workmanship are essential to this class of bridge, and the attention given to these points is amply repaid by the facility gained in erection abroad. A series of spans can be erected on piers or columns to carry a roadway for any distance.

Length of Span.	Length of Longest Piece.	Weight of Heaviest Piece.	Total Weight.	Price delivered in London, Liverpool, or Hull.		
Feet.	Feet.	Cwt.	Tons.	£	s.	d.
20	20	14	6	96	0	0
40	20	13	12	195	0	0
60	20	14	20	328	0	0
80	20	14	30	514	0	0
100	20	15	42	720	0	0

SUSPENSION BRIDGES.

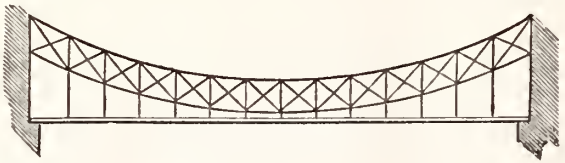
SUSPENSION bridges have hitherto been chiefly used for spans too great to be covered by arches or girders at a reasonable cost, and sometimes also in cases where, though the span is not excessive, only a roadway for foot passengers is required.

In ordinary suspension bridges the roadway is suspended by hanging rods, from chains which stretch from pier to pier; the whole weight of the platform, and the moving loads upon it being thus transmitted through the chains to the piers. Whatever the length of span, the platform forming the roadway is in all its parts of uniform strength; the chains from which it is suspended alone increasing in strength and weight per foot as the span increases.

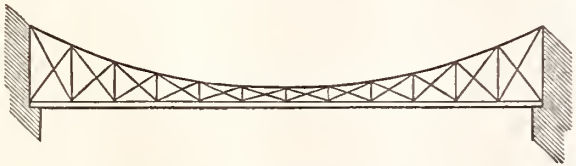


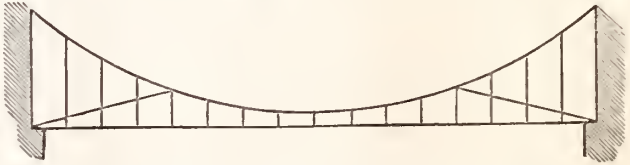
Longitudinally, the structure is flexible in respect of the chain and the platform, and this is shown whenever the bridge is loaded at one end more than at the other by a moving load, or is subjected to wind pressure above or below. The chain then suffers an alteration of its proper line, and the platform being also flexible, follows it by assuming the shape of a wave, as shown by the dotted lines in diagram. This state of disturbance is only gradually redressed, and the bridge meanwhile undulates. Deflection in a suspension bridge, arising from the elasticity of material, is an entirely independent kind of deformation, and is common (though in other than suspension bridges to a less degree) to all bridges of iron. It is in a suspension bridge very small as compared to the vibration and undulation, and is not at all damaging to the bridge.

Improvements on the ordinary suspension principle have hitherto been directed towards preserving the true catenary or curve of the chains, and thus lessening the undulation. Different methods have been tried for doing this. In some cases two chains—one above the other—have been used, and these have been braced together by



diagonal bracing, but leaving the platform under the same conditions as before. Another and a more successful plan has been to brace the single chain to the platform, thus making the two flexible parts of the structure share the effects of the moving load, and partly check them. The same improvement has also been effected by keeping the

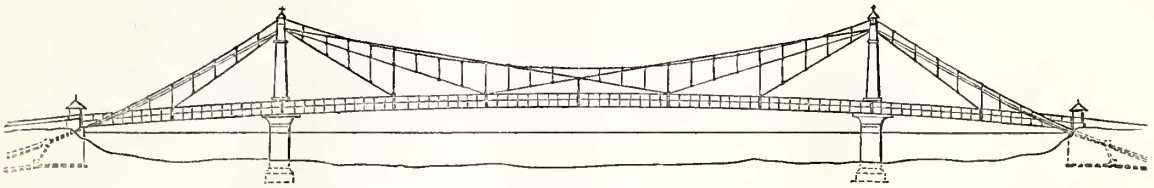




two points of the curved chain which are most liable to deformation in their proper places by attaching them to the piers with short straight chains, as shown in diagram. All these methods diminish the undulations from flexibility, but do not remove them.

The most recent alteration in the form of these structures is the *Rigid Suspension Bridge*, invented by Mr. R. M. Ordish. This is an improvement entirely unlike those just alluded to. It really is a girder bridge with

a number of spans, the weight of the platforms and the moving load being transmitted to the piers or abutments by inclined straight chains, which take a direct tensile strain only. These chains are retained in straight lines by being



suspended from the curved chain by vertical rods. The load upon the curved chain under all circumstances being the same (namely, the weight of the inclined straight chains), the proper curve is maintained in all cases of equal or unequal load on the platform. Bridges made on this plan are rigid and free from undulation under all circumstances and all descriptions of traffic. What was previously alluded to as *deflection* still exists in the points supported by the inclined straight chains, but as pointed out before, this is a minor fault in suspension bridges.

The economy of material that is obtained in bridges of this kind permits their construction at moderate cost. A bridge 820 feet long, with a clear central span of 492 feet, manufactured in Austria, has been successfully erected over the river Moldau, at Prague, on Mr. Ordish's plan. Other bridges on the same principle are also in course of construction.

Andw. Handyside & Co. will furnish estimates of cost for suspension bridges, and undertake their manufacture.

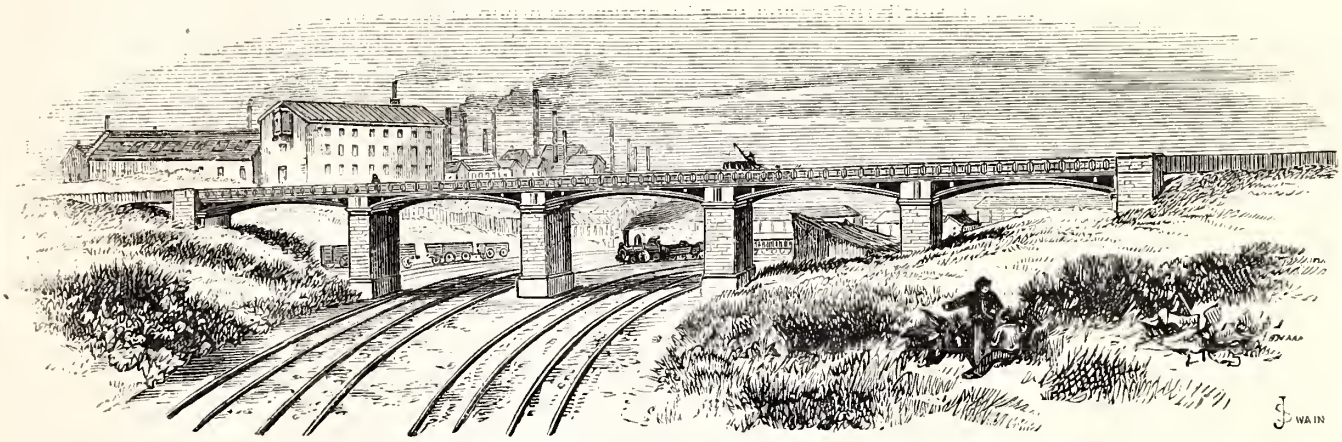
CAST-IRON GIRDERS AND BRIDGES.

ALTHOUGH in modern use wrought iron has to a great extent superseded cast iron, the latter is in some cases preferable, and is more convenient for the facility with which it can take every variety of shape. It is well able to bear exposure to the weather, is not so liable as wrought iron to deterioration by rust, and if kept painted with ordinary care will prove the most enduring. In the use of cast iron the metal is of course considerably thicker than in structures of wrought iron; and any loss that may accrue by exposure to the weather reduces the strength in less degree. That is to say, the oxidation and destruction of one-eighth of an inch is of much less consequence in iron one inch thick than in plates half-an-inch thick.

For very small spans the parallel girder of ordinary section is generally used, the lower flange containing a much larger proportion of metal than the upper, this being necessary because of the great power of resistance to compression and the weakness in tension possessed by cast iron. For girders more than twelve feet long, although the same proportions in section are observed, the beam is generally curved at the top so as to give a greater depth and strength in the centre. The transverse strain to which a girder is subjected, demands more attention to the quality of material than is necessary in columns and stancheons, which take a dead compressive weight. It too often happens that a very low quality of metal is employed for girders as well as for columns, and renders necessary for safety heavy sections which, when excessive, are liable to unsoundness. Girders of the ordinary form are amongst the cheapest kind of castings, and can be bought from £6 10s. to £9 per ton, according to the quality of the iron.

In bridges cast iron has proved most efficient, and shows even now to great advantage in some of the earlier specimens of this branch of engineering, which were contrived at a time when wrought iron was not made in the many shapes now available for the purpose.

Cast iron is adapted for the strains peculiar to an arch, and it is in bridges of this form that it is oftenest



ROAD BRIDGE AT NOTTINGHAM.

used. Southwark Bridge, over the Thames, may be given as an example. It was erected in 1819, and consists of three arches, each the segment of a circle, the middle arch having a span of 250 feet, and the two end arches 210 feet each.

Up to 40 feet span arches may be made in one casting, and in two if not exceeding 80 feet; beyond these dimensions it is most convenient to use a number of segments abutting on one another. Cast iron is peculiarly adapted for bridges where it is desired to give elegance of shape or ornamental detail; and there is a wide scope for the invention of designs in this material.

Single span bridges over small rivers, and in conspicuous and public places of importance, or a succession of spans if the occasion demand it, can be erected at less cost than in stone. And^{w} Handyside & Co. have made many such bridges, and their large foundry affords every facility for the largest works of this kind.

The preceding sketch shows a road bridge erected by And^{w} Handyside & Co., in 1862, over the railway at Nottingham. The bridge is 175 feet long, divided into five spans of 35 feet, in each of which there are ten arched girders springing from stone piers. These main ribs are each cast in one piece, and are crossed by short "skewback" girders of cast iron, on which brick arches are built to carry the roadway. A trough is formed in the centre of the bridge for gas and water pipes, and this is covered by "buckled" plates. The parapets are composed of cast standards and wrought-iron plates. There are 314 tons of iron in this bridge. The general price for such work would be about £9 per ton.

ERECTION OF BRIDGES.

THE prices of bridges already mentioned have in no case included the cost of erection *in situ*. This is an element of expense for which no general rule can be stated, as it depends very much upon local circumstances. From seven to twenty per cent. on the first cost of the bridge is the narrowest range of difference that can safely be given. The erection of bridges has become so distinct a branch of work, that it is best, if possible, to employ men who have had this special experience, and who can judge in each case the readiest methods of procedure. For piers formed of cylinders, a fixed staging is necessary, and this involves timber, piles, and pile driving. In most cases of this kind very strong platforms are needed, and in rivers which are tidal or liable to be flooded, a sufficient height for different levels is of course requisite. For the insertion of screw piles, floating rafts or barges are sometimes used; but where it is possible, a fixed staging is much to be preferred. A strong framework is needed to hold the pile in its place while it is being screwed down, and it is desirable to have more than one bearing place to guide the pile as it revolves and descends. It is usual to fix upon the top of the pile a capstan, fitting to it like a key, having each of its radial

bars strongly braced together by screw couplings. A rope round this is connected on both sides to an ordinary crab or winch, and as equal a strain as possible is given to the two opposite forces. It is, however, somewhat difficult with an elastic rope to keep the two ends equally taut, and to prevent occasional jerks; while sometimes the winches are unable to exert sufficient power. Having experienced these difficulties, Andw Handyside & Co. have used an apparatus by which the ropes and winches are dispensed with, and worm wheels and gearing adopted instead. A machine of this sort can, if required, be supplied with bridges for £100 to £120.

Many obstructions are met with in screwing piles, and sometimes large stones have to be avoided and passed. The employment of divers may become necessary, and this adds greatly to the expense of the work.

If the erection of a bridge extend over a long period, it is very convenient to erect a travelling crane over the whole structure, and this, in many cases, will amply repay its cost by the increased facilities it gives for moving heavy loads. Always very useful, it requires discretion and experience to determine when it is actually necessary or expedient. When the level of a bridge permits it, it is possible to evade some lifting work by running the first girders into their places from the abutments. Thus only a portion of their weight has to be sustained in the air, and as each span is fixed it can serve as a roadway for the carriage of the next.

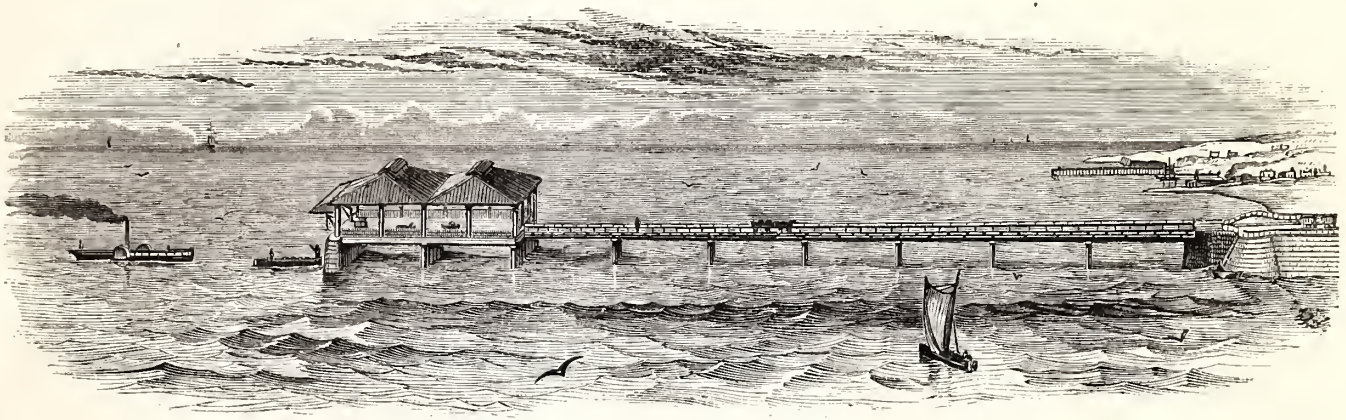
Single derricks can carry immense weights if properly sustained by "guy" ropes, but in many cases it is necessary to have two or three "legs" to sustain the load.

In all cases great caution as to the strength of ropes and chains should be observed; and it will always be found that the expense of careful preparations at the commencement will be amply repaid by the freedom and confidence which they secure.

PIERS AND JETTIES.

THERE are so many points of resemblance between bridges and piers, that much of the information given about the former might be repeated here. There is the same diversity of design depending in each case upon the local features of the site, and it is only possible to give some idea of the general forms adopted.

Where there is a hard, rocky bottom, solid wrought-iron columns are generally used for the first supports, and these are stepped at the foot into holes cut for the purpose. In gravel or sand, solid or hollow columns can be forced down, and the screw pile is the most convenient for this purpose. The pneumatic plan, alluded to under the head of bridge piers, has also been successfully used for hollow columns. The depth to which the piles or columns descend depends entirely on the strata and the distance necessary to reach a firm bearing, and in some cases columns of great length are needed. In a group of piles arranged to form a pier, the outer piles instead of standing vertically are generally inserted at an angle, so as to secure a wide supporting base and lateral firmness. Strong bracing is required to unite the several columns into one complete structure. As it is seldom necessary to leave a clear passage for vessels to pass under the roadway, as in a bridge, the supporting piers can be placed near together, and strong horizontal and diagonal bracing may occupy the intervening space. In exposed situations the real security of the structure depends less on the resistance offered to the waves than on the unrestricted passage left for their movements; that is to say, while a strong wall of unbroken surface could not resist the enormous force of the water, an open network will allow it to pass harmlessly through. Where it is required that the pier shall act as a breakwater, a much stronger structure is needed, and heavy stonework should be placed behind and between the ironwork, to which, if necessary, a smooth surface of iron plates can be attached, to take the first shock of the waves. The form of superstructure for a pier depends mainly on the distance between the supports. In ordinary cases a span of from twenty to thirty feet is most convenient, and plate or lattice girders form the supports between the columns, the



MAZAGON PIER, BOMBAY.

number of girders in each span being regulated by the width of roadway required. Sometimes much longer spans are adopted, and stronger girders are required. These can then be made with a flat curve springing from the piers near the water line, or arches of various forms can be employed. All the details of a bridge are then involved, and there may be sufficient head-room for the passage of vessels below the roadway. The flooring may be formed of iron plates attached to cross girders and covered with ballast, or of timber caulked like a ship's deck. A neat iron parapet or railing completes the pier. It is usual to make the pier head of greater width than the roadway, and to arrange staircases and landing floors for the different levels of the tide; and this of course adds considerably to the cost.

A pier lately sent out to India by Andw Handyside & Co. may be described as the type of an ordinary structure at moderate cost. The pier, as shown in the engraving, is 336 feet long and 30 feet wide, and forms a

continuation of a stone pier previously erected. The length is divided into nine bays of 34 feet, at each of which intervals four cast-iron columns 16 ins. diameter are placed, the lower ends forming piles upon which screws are cast. These piles are screwed down to depths of from 8 to 12 feet into the bed of the sea. Resting upon the columns, and uniting them together, are heavy capsills of cast iron, 30 feet long, forming the breadth of pier, and carrying the longitudinal girders. The roadway in each bay is sustained by seven of these girders, which are of wrought iron, having a single web two feet deep. Upon the outer girders, and in a line with them, panelled fascia plates 16 ins. deep of cast iron are fixed, increasing the apparent depth of girders to 3 feet 4 ins. The roadway is formed of square "buckled" plates rivetted to the girders, and stiffened at each seam by strong T irons. Upon these plates the ballast for the road is placed. A simple railing with strong wrought-iron standards is fixed to the longitudinal fascia plate. The pier is widened out in the last two bays to 60 feet, and iron sheds for protecting goods are erected. Cranes for unloading vessels are fixed under the overhanging eaves. The total weight of the pier, exclusive of the sheds, is 200 tons of cast iron and 250 tons of wrought iron. The cost of a similar one would be about £7,300. If made only 15 feet wide, the price would be reduced to £3,800.

IRON ROOFS.

IN designing iron roofs it is assumed that there may be a wind pressure of twenty-five pounds per square foot, and a weight of snow of fifteen pounds. These, added to the weight of the roof itself, give the total load to be sustained, and the strain upon the iron under these circumstances should be about one-fourth—and should never exceed one-third—of the breaking weight. The remarks given on page 8 as to the quality of material and workmanship in bridges applies generally to roof work also. Wrought iron of from twenty to twenty-two tons breaking strain ought to be employed. By simplicity of construction expense may be saved; welding at the joints and other parts should be avoided as much as possible, and wherever welds in the iron are necessary the greatest care is needed to ensure a strength equal to the other parts of the structure.

Iron roofs may be generally divided into two classes, trussed roofs and arched roofs, and of both these kinds there are many varieties and combinations. Trussed roofs are complete structures retaining within themselves all the strains to which they are subject, the columns or walls upon which they rest having to sustain a vertical pressure only. For mere purposes of utility the trussed roof is generally preferred, as in almost all cases it is the more economical. For roofs of small span, trusses, as shown in figures 7 and 8, are usually adopted, but beyond seventy or eighty feet other modifications of the triangular system are used, and those shown in the engraving are described in the following pages. The strains occurring in trussed principals can be calculated very exactly, and the material disposed accordingly.

The arched roof is generally used where a certain architectural effect is desired, besides the mere strength necessary to sustain the covering. In any roof without ties the tendency of the roof to spread out has to be resisted, and in an arched roof, therefore, a lateral strength must be given to the walls or columns. Walls are sometimes

made sufficiently strong by buttresses, or where a single wall has not sufficient strength to resist this outward pressure, a portion of the thrust may be taken to a second or outer wall. A double row of braced columns also affords a sufficient width of base to take the pressure of an arched roof, and that over the Agricultural Hall, shown in figure 1, partly illustrates both these methods.

Dome-like roofs cannot strictly be described as either arched or trussed, as the thrust is taken by a ring which being part of the roof receives the feet of the ribs. The rectangular Winter Garden at Leeds (illustrated and described at the end of the book) has a roof framed on the principle of a dome, though this is not immediately indicated by its appearance.

Wherever it is possible, a roof should be arranged so that there is a repetition of the parts, and on the extent to which this is effected the cost of the roof very much depends. A building divided into equal spaces, and in which the principals occur at regular intervals, is the cheapest that can be adopted. The prices of roofs are generally calculated at per "square" of 100 superficial feet. Rectangular buildings may be covered with roofs having gable ends, or the ends may be "hipped." The hipped portion, however, is more expensive than the ordinary part of a roof, the frame-work requiring more labour, and the covering being cut to waste. As an approximate rule, one-third must be added to the general price per square for that portion of the area which is covered by the hip. Against this cost of the hip must be considered the saving effected in the material that would be needed if gables were used.

The prices are given here in such a form as will enable a purchaser to separate generally the cost of the framework from that of the covering, of which there are different kinds. Slates, glass, zinc, and corrugated iron are the principal materials with which iron roofs are covered, and these are of course used as place and circumstances may demand. Nothing can be better generally than good slates, which are durable and easily fixed. The weight of them, however, is considerable (from six to seven hundredweight per square), and for roofs to be erected abroad it is found more convenient to use zinc or corrugated iron, the latter being generally coated with zinc, and known as "galvanized iron."

Since the first introduction of zinc in this country, as a material for roof covering, there have been very great improvements in its manufacture and in the methods of applying it. Zinc corrugated in the ordinary manner, like the corrugated iron shown below, can be attached to either curved or sloping roofs. It may be attached to a roof without boarding, but as the sheets are not so strong as those made of iron, it is necessary, if boarding is not used, that the framework of the roof shall be close enough to give sufficient rigidity to the covering. Zinc is also laid in flat sheets like lead, with wood boarding, and wood rolls about three feet apart. The plan most recently adopted for roof covering is that known as "Italian Corrugation," by which the use of boarding may be dispensed with, and the process of fixing rendered simple and easy. The wood rolls shown in sketch are three inches deep and two inches wide, and are attached directly to the iron frame-work of the roof, the sheets being corrugated to fit the rolls, and overlapping each other at the joints. Zinc sheets are made of different thicknesses, varying from 13 to 16 of the zinc gauge, the thickness increasing as the numbers advance. Nos. 14 and 15 are the gauges generally adopted.

When well laid, zinc forms a light, strong, and neat covering, and though subject to oxidize, the oxide does not scale off like that of iron, but forms a permanent coating on the zinc, impervious to the action of the atmosphere, and rendering the use of paint unnecessary.

Corrugated galvanized iron is a material much used for covering iron roofs, and possesses several advantages. It is light, easily packed, and not liable to breakage. Its form gives it strength, and allows it to be fixed with a limited amount of frame-work. In pure air it lasts well, but in the vitiated atmosphere of London and other places where there is much exposure to the influence of coal gas, the action upon the zinc will in time expose the iron to the weather. But this may be prevented if the sheeting is painted, which is best effected by applying the paint when the first gloss has left the new zinc coating. Galvanized iron sheets are made of different thicknesses, designated by the numbers of the Birmingham wire gauge, the thickness

decreasing as the numbers advance. Nos. 16 to 20 are the gauges generally used. Roofs of either zinc or galvanized iron can be made double, if required.

Glass is used in conjunction with all other materials, and the extent to which it is employed of course depends upon the amount of light required. The following may be taken as average prices and weights of roof covering per square of 100 superficial feet, the measurement not being of the area of ground covered, but of the necessary quantity as determined by the angle of the roof.

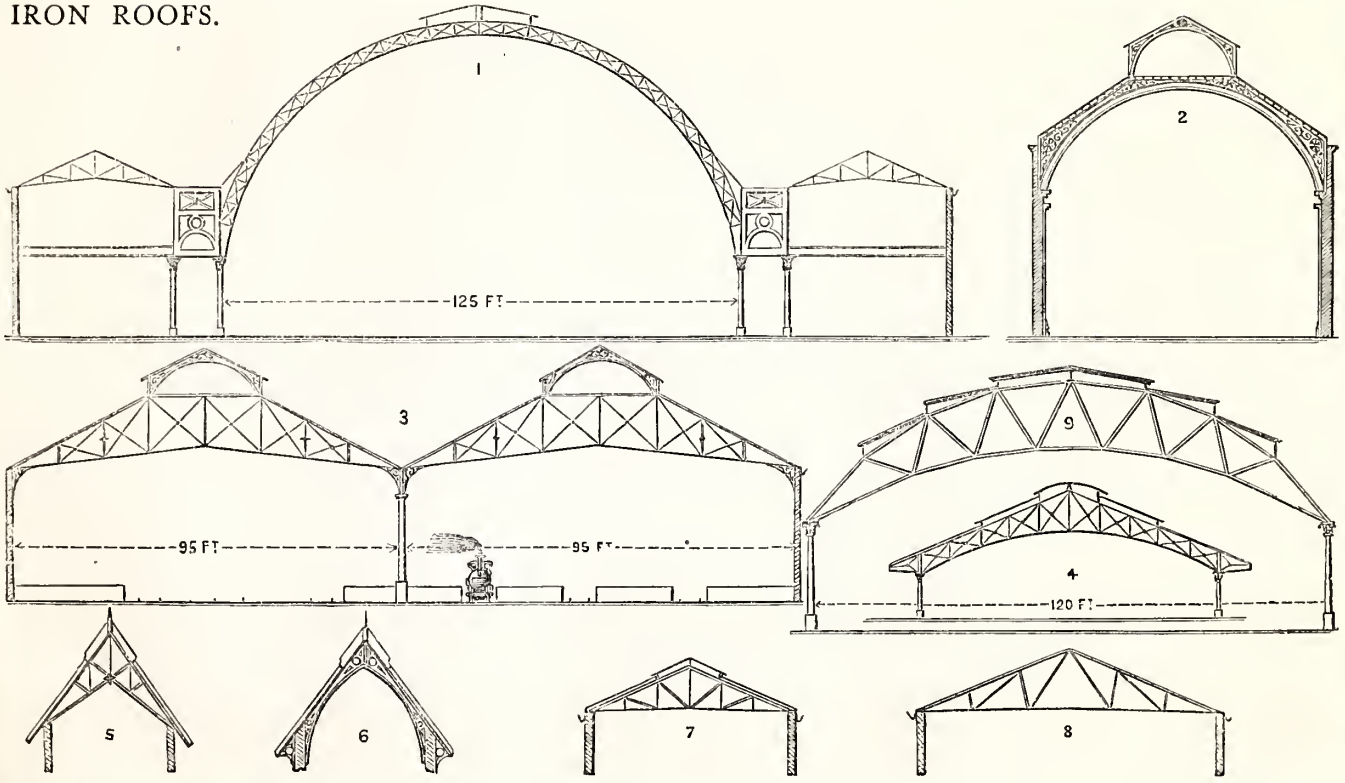
Average Prices and Weights of Roof Covering per square of 100 *feet.*

Zinc, Ordinary Corrugation	13 zinc gauge ...	£2 10 0	144 lbs.
Ditto ditto	14 ,, ...	2 15 0	170 ,,
Ditto ditto	16 ,, ...	3 5 0	203 ,,
Ditto, Italian Corrugation, including wood rolls and fastenings	13 ,, ...	2 10 0	164 ,,
Ditto ditto ditto	14 ,, ...	2 15 0	180 ,,
Ditto ditto ditto	16 ,, ...	3 5 0	211 ,,
Galvanized Corrugated Iron, including fastenings ...	16 B. W. G. ...	3 3 0	380 ,,
Ditto ditto ...	18 ,, ...	2 14 0	280 ,,
Ditto ditto ...	20 ,, ...	2 3 0	224 ,,

Fixing any of the above costs about 12s. per square. Curving sheets cost about 3s. per square extra. Packing for shipment about £1 per ton extra. Glass, including wooden skylight bars, varies with the thickness and size of sheets from £2 to £6 per square.

Fig. 1 on page 35 is a cross section of the Agricultural Hall at Islington, designed by Mr. Frederick Peck. The entire building, except the outer walls, is constructed of iron made and erected by Andw Handyside & Co. in

IRON ROOFS.



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1862. The central roof has a clear span of 125 feet, the crown of the arch rising 70 feet from the ground. It is the largest roof yet erected* with principals without ties between the walls to take the horizontal thrust. The main ribs or principals are of open lattice work, 3 feet 6 ins. deep, and are placed 24 feet apart, with longitudinal trussed purlins between them, the whole being strengthened by diagonal bracing. The "thrust" of the roof is taken by the double row of columns, and through the girders of the gallery to the outer walls. The side roofs over galleries are of ordinary trussed principals of 36 feet span. The building has a total length of 384 feet, and is 217 feet wide; it is covered with slates and glass, and contains 820 tons of iron. A roof of this description is not one of the cheapest, but it has a light appearance, and may be used where a clear open space is desired. The total cost, exclusive of erection and covering, may be taken at £12 15s. per "square."

The Inns of Court Hotel has its inner court or quadrangle covered by a roof, of which diagram No. 2 shows a section. The roof was constructed by And^{w} Handyside & Co. in 1865. The arched ribs are framed of wrought iron, with the triangular spaces filled in with cast-iron panels of an ornamental character. This roof gives a clear space, and affords great scope for decoration within, there being no necessity for hiding any of the constructive details. The ventilation framework is entirely of cast iron, the spandrils being ornamented, and the whole roof covered with glass. The roof is 69 feet long, and 39 feet span, and the weight of ironwork about 30 tons. The cost of such a roof would vary with the amount of ornament required.

Diagram No. 3 shows a cross section of the Broad Street Terminus of the North London Railway, which is covered by a roof made and erected by And^{w} Handyside & Co. in 1865. The roof is 450 long, and 190 feet wide, divided into two spans of 95 feet, which spring from the outer walls and meet on a line of centre columns. The principals are of wrought iron, and their upper members are plate girders 9 ins. deep, the ties and other parts being of round bars, except the two vertical struts of cast iron. Ventilation is provided by the ordinary side louvres, above which the roof is carried on ornamental cast-iron spandrils, and diagonal wind ties assist in bracing the principals

* The roof of the Midland Railway Terminus, now (1868) erecting in London, is 250 feet span.

together. The building has gable ends, and is covered with slate and glass; the total weight of ironwork being about 780 tons. The cost of a roof of this description would be £14 per square, without covering and erection.

Diagram No. 4 is the section of a roof 86 feet wide, with a span between columns of only 70 feet. It is shown complete in sketch on page 43, where it is described fully, with weight and price.

The Amsterdam Station of the Dutch Rhenish Railway is covered by a roof as shown in diagram No. 9. It was designed by Mr. R. M. Ordish, and made by And^{w} Handyside & Co. in 1863, and was then of somewhat novel character. The station is 300 feet long, 120 feet wide, and is supported on cast-iron octagonal columns placed 25 feet apart, and the building being in a very exposed situation, these are secured very strongly to the foundation piers. The principals, which may be termed bow-string trusses (the arch or main compression member is of cast iron), are each 120 feet span from centre to centre of shoes. The rise of cast-iron arch is 30 feet, and the rise of the tie bars 17 feet, giving a depth of 13 feet in the centre. The word arch is used in describing the compression member of the principals, but it is in fact polygonal, being composed of straight lengths of cast-iron tubes, 8 ins. diameter, turned truly at their abutting ends. The tie bars consist of two flat links 4 ins. × $\frac{7}{8}$ in., the holes for the connecting pins being bored, and the whole of the links proved with a strain of 12 tons per inch, without any *permanent set*. The breaking strain for the links would be about 24 tons, the actual weight they may have to bear being about 6 tons. The diagonals each consist of two flat bars 6 ins. × $\frac{5}{16}$ in.; the pins and bolts for these and other principal connections being turned, and the holes through which they pass accurately bored to fit. The purlins are of cast iron, glazed with sheet glass. The gutters are in one length between columns, and act as purlins for supporting the roof covering, the rain-water escaping down the columns. The wind ties are bars 4 ins. × $\frac{3}{8}$ in. Ventilation is provided at the top of the roof by means of cast-iron openwork ridge purlins, with a cover of corrugated iron, No. 16 gauge. The cost of a roof like this, including columns and holding down bolts, but exclusive of foundations, covering, and erection, would be about £7 per "square." This is a low price, a great saving being effected by the use of cast iron in the principals.

Nos. 5 and 6 are roofs made at the Britannia Ironworks, Derby, for the Deccan College, India, and as will be

seen from the diagram, are of somewhat peculiar construction. No. 5 shows a trussed principal with rafters of T iron, struts of channel iron, and ties of ordinary bars. The span is 21 feet, and at the junction of king rod with tie there is an ornamental rosette. This roof is 330 feet long, and could now be re-produced complete, without covering, for £9 per "square." No. 6 is the same pitch as no 5, but is of a different construction, each principal being formed of a wrought-iron spandril, composed of angle iron and plates, the latter being pierced to a neat open-work pattern. The triangular spaces at the springing and the point of the roof are filled in with light ornamental ironwork, and brackets of the same character help to sustain the overhanging eaves. The building is 70 feet long, with gable ends, and the distance between side walls is 25 feet. Ventilation is provided by side louvres at the top of the roof, which is there raised above the rafters, as shown in diagram. A small roof of this size could be made for about £13 per "square," exclusive of zinc covering.

Nos. 7 and 8 are roofs of the kind generally used for spans of from 30 to 70 feet, where only a strong useful construction of the cheapest form is wanted.

No. 7 is a roof 86 feet wide in two spans, made by And^{w} Handyside & Co., for the Shell Foundry, Woolwich Arsenal, and is of a similar kind to the small side spans of the Agricultural Hall (diagram No. 1). The rafters and struts are of T iron, and the vertical rods and horizontal ties are round bars. The purlins are of T iron, attached to small angle iron cleats on the rafters, and the upper part of the roof is raised so as to afford ventilation at the side louvres. A roof of this kind, erected inclusive of gutters and a covering of corrugated iron, would cost about £11 per "square."

No. 8 is of almost the same kind as No. 7, except that there is no vertical king rod, and that the queen rods are diagonal struts, the diagram showing a roof of 48 feet span, made by And^{w} Handyside & Co. for the Bilboa Railway, in Spain. There are no ventilating louvres.

Many other forms of iron roof besides those above mentioned are made by And^{w} Handyside & Co., but it would be impossible to enumerate the differences in detail that have been designed to meet special cases. When

required, original designs can be prepared, or assistance can be given in working out the details of any designs that may be supplied. The prices below give in a convenient form those previously mentioned for plain roofing. It may be taken as a general rule that the cost per "square" increases with the size of the roof.

Approximate prices per Square of ground covered.

For roofs of ordinary form, built with framed trusses, without covering, but inclusive of purlins, gutters, and ventilating arrangements :—

Spans not exceeding 30 feet...	...	...	...	...	£5	5	0
,, ,, 40 ,, ...	...	...	...	...	6	2	6
,, ,, 60 ,, ...	...	...	...	...	6	10	0

The prices per "square" for covering are given on page 34, and these, added to the prices above, show the total cost of plain roofing.

And^{w} Handyside & Co. will supply roofs for buildings which are not rectangular, and which either in size or design may require peculiar construction.

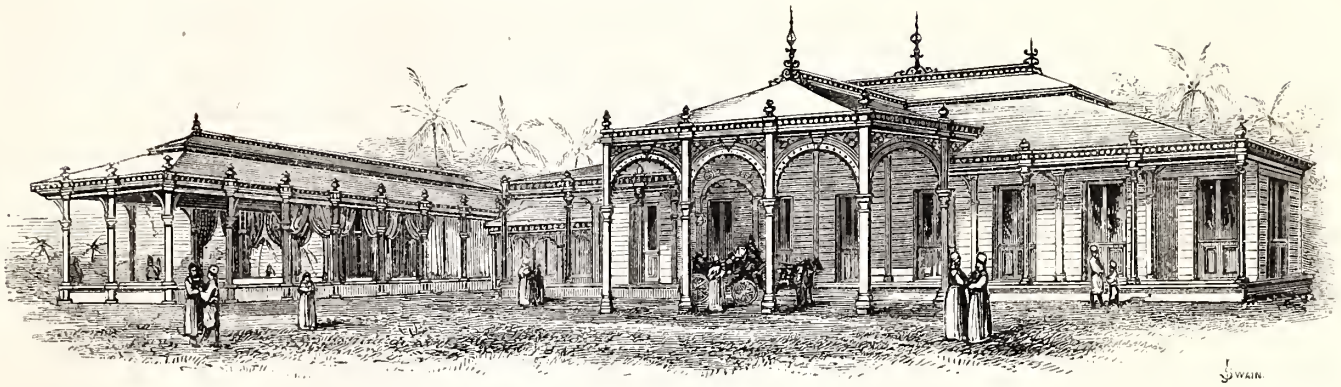
IRON BUILDINGS.

CONTINUAL progress is being made in the right application of iron to building purposes, and the demand for structures of this material increases rapidly. Many engineers possessing an intimate knowledge of the capabilities and qualities of iron give special attention to this branch of constructive ironwork; attaining a much higher taste and fitness in their designs by giving to them an architectural character, in keeping with the material employed.

Andw Handyside & Co. have had much experience in the manufacture of works of this kind, and are able to supply iron buildings suitable to any specified purpose, and to give assistance in the arrangement of details to those who supply their own designs. For most ordinary buildings, the framework of cast and wrought iron can be surrounded by sheets of corrugated iron, galvanized or painted, and this method allows a building to be sent to the place of erection, complete in every respect, and needing no brickwork whatever. Warehouses, sheds, workshops, dwelling-houses, can be thus constructed, and packed in convenient pieces for shipment or other carriage. For hot countries, where a single roof of iron would be unendurable, a double one is provided, having an air space between the outer and inner coverings, and this plan preserves a low temperature within the buildings.

Where skilled labour is expensive, and the ordinary materials of stone and brick not easily procurable, ironwork is a most convenient substitute, and its use is becoming more general. Buildings may also be constructed with a framework wholly or in part of iron, the spaces being filled up with white or coloured tiles fitted under iron sills and lintels. The substance of the wall can also be composed of brick or concrete, the latter possessing great strength; or, if preferred, an empty space can be left.

Buildings framed in this way are durable and fire proof, and are always clean in appearance. Where the tiles are white they reflect the light instead of absorbing it—a matter of great importance in narrow streets. Where



IRON BUNGALOW.

space is valuable, as little of it as possible is wasted by the thickness of walls; and where light, open spaces are needed, the supports can be so arranged as to be few in number.

In designing rectangular iron buildings, it is expedient that the plan be arranged in equal squares, so that the length and the breadth shall be divisible by the same figure. This allows the columns or main parts of the structure to be placed at equal distances along the sides and ends, and affords great facilities for the economical disposition of the material.

The engraving shows a Bungalow, or dwelling-house for India, arranged as a suitable residence for the climate. It is made and erected entirely in England, so that it can be afterwards refixed in India without difficulty. The area covered by the roof is 5,000 square feet, but of this one-half only is within the walls, the remainder forming

a verandah 8 feet wide, a carriage entrance 25 feet by 17 feet, and an open saloon 25 feet by 17 feet. The whole of the building, except the carriage entrance, is raised two feet from the ground, to prevent the admission of damp. The framework of the walls consists of cast-iron columns 8 feet apart, resting on bases of concrete, and connected on the top by girders of cast iron forming a gutter and cornice. Each wall column is connected with a verandah column by an ornamental spandril at top and a girder at the bottom, and the rain-water is carried through the verandah columns to outlets outside the base.

The building contains—

One dining room, 25 feet by 16 feet
One drawing room, ditto
} Joining with their 25 feet sides.

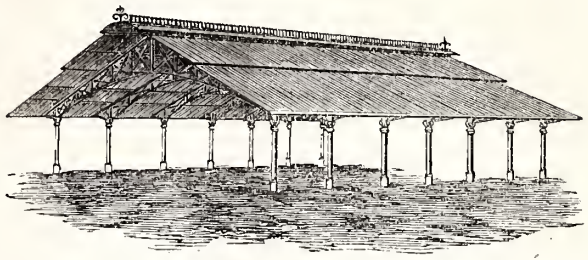
Four bed rooms, each 16 feet by 16 feet.

Four bath rooms, each 8 feet by 8 feet, and each belonging to a bed room.

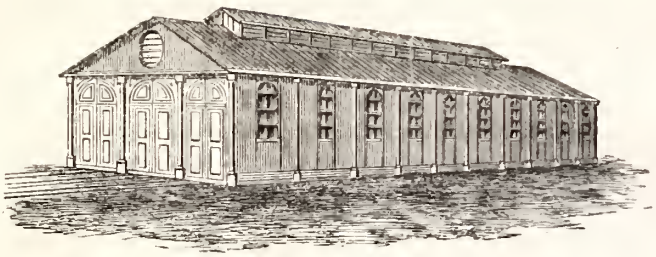
Besides these separate chambers, there is a smoking room, occupying the same position at the back that the carriage entrance does in front. The side wing of the building, shown on the left in the engraving, is available for stable, coach-house, kitchen, &c. The sides of these offices are left open, and can be enclosed by curtains or boarding after the house is erected.

The walls of the main buildings are 15 ins. thick, each consisting of an outside wall of iron plates, with an inside boarding, leaving about 10 ins. space between the wood and iron. The windows are 3 feet 6 inches wide, and can be used as doors, and the two large rooms have each a door 8 feet wide, leading to the outer saloon and carriage shed respectively. These doors are 9 feet high, and above them are fixed double "venetians," 4 feet high, making the total height of opening 13 feet. The doors and windows are double. The roof is a framework of iron, covered outside with corrugated iron and inside with boarding, the latter being suspended on the ties of the principals to form a flat ceiling. There is thus a space between the coverings; but these can both be made double, if required. There is ventilation on the top of the roof. The price of a building like this, complete, with woodwork, glass, wall paper,

and with windows and doors as described, fitted in England, marked for erection, and delivered properly packed at any English port, is £2,800. The approximate weight for shipment is 120 tons.



The illustration shows the shed (a cross section of which is given in diagram No. 4, page 36) made by Andw. Handyside & Co. in 1866, for covering a portion of the Wellington Pier, Bombay, the principal landing place in that city. The shed is 96 feet long and 86 feet wide, and is intended as a shelter for carriages in waiting. The span between the columns is 70 feet, the rest of the width being made up by an overhang of about 7 feet beyond the columns on either side. The principals are each divided into ten bays, having cross bracings between the verticals, and these being made alike in section and in their connections, act either as struts or ties, and serve equally to resist load pressure from above or wind pressure from below. The two end verticals on each principal are formed by the upper part of the columns, the whole being one casting; and the connection of columns with principals is thus absolutely rigid. There is abundance of ventilation, which is provided near the ridge, and also about half-way from ridge to gutter. The purlins are of wrought iron; there is a longitudinal bracing in centre of span, and there are diagonal wind ties close underneath the covering. Rain-water is carried from wrought-iron gutters by wrought-iron



IRON BUILDINGS.

pipes to the columns, through which it passes to the ground. The covering is of corrugated iron sheets, galvanized. The total area covered is 8,250 feet. The building was designed with a specially ornamental character, the columns being octagonal, with enriched capitals. The total weight of roof is 35 tons, and the columns weigh 15 tons. The price of such a shed as this, complete, with covering, is about £1,350, or £16 7s. 6d. per square; but the same area may be covered in a plainer manner for a less sum by a roof of the kind shown by diagrams 7 and 8, on page 36.

The first engraving on this page shows a building suitable either for this country or abroad, and which can be used as a warehouse or as an engine shed on a railway. It is 100 feet long by 30 feet wide, and is enclosed at the sides by sheets of corrugated galvanized iron, and at each end by three doors. The frame-work consists of plain columns or stanchions, which divide the building into ten bays, and to which the corrugated sheets are attached. These columns are connected at the top by gutter girders, the rain-water escaping down the columns. Over each column is an ordinary trussed roof principal, and the covering is of the same material as the sides of the shed. Over eight of the ten bays ventilating louvres are fixed with a skylight of glass above. Iron casement windows occur between each column, and there is a circular light in the centre of each gable end. The cost of a shed like this,

fitted together, and with glass, &c., as specified above, packed and delivered f. o. b., would be £660. The weight for shipment would be about 40 tons.

The last sketch is a design for a shed open at the sides, adapted for storing certain kinds of goods, or for sheltering railway carriages. The framework consists of plain hollow columns, from the upper part of which spring light iron spandrils, joining each column to its neighbour, and rendering the framework rigid. Above these is a gutter cornice, from which spring the roof principals, carrying the galvanized covering. As will be seen by the sketch, the roof is hipped; and to keep the entire width clear at ends without a centre column, a lattice girder carries the gutter and roof between the end columns on each side; ventilating space is provided along the ridge. For three feet below the gutter the sides of the shed are of galvanized corrugated iron. The cost of this building is £565, and the weight 36½ tons.

The sketches given here show of course only a very few of the different kinds of iron buildings made, but they may be taken as fair examples of what can be done; and Andw. Handyside & Co. will, at any time, supply iron buildings arranged and designed in each case for the special purpose in view. For iron structures of a more ornamental character, particulars will be found at the end of the book.

STEAM ENGINES.

"HORSE POWER."

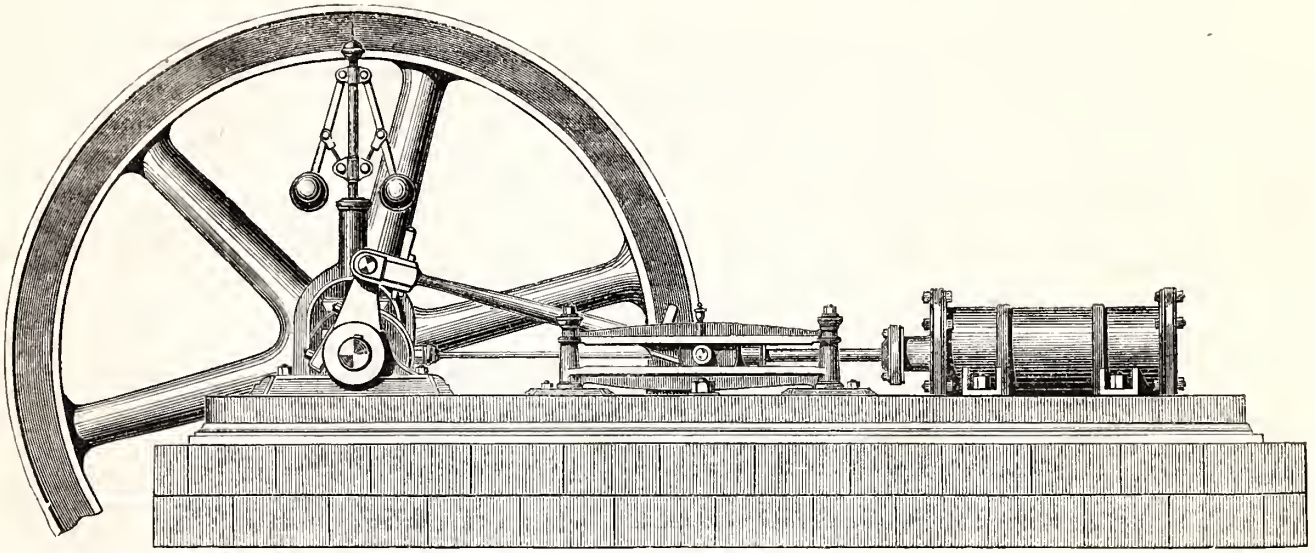
AS an indication of the capacity of a steam engine, this term, as now used, is arbitrary, and does not give an exact measure of value. It refers to the only standard yet adopted, namely, that of Watt, who gave as the power of "one horse," a force capable of lifting 33,000 lbs., one foot high, in one minute; but with modern improvements in construction, and by the use of high pressure steam, engines of the same dimensions as formerly possess much greater power. The total pressure upon, and the speed of the piston, determine the full strength of an engine; and after deduction of what is consumed by friction within the machine itself, the net amount of its power is obtained. The size of engine, therefore, necessary for a certain performance depends entirely upon the pressure and speed at which it is to be worked.

A precise analysis of the force actually generated in a steam engine is obtained by an instrument called an Indicator. The real or "*indicated horse-power*," stated by this means, very largely exceeds the figure of "*nominal horse-power*," given by the standard at present used in the commercial valuation of engines.

BEAM ENGINES.

THE Beam Condensing Engine at the present day differs but in detail from that invented a hundred years ago by Watt, and for regularity of motion and long endurance, it cannot be excelled. The well-balanced moving beam gives a pendulum-like exactness, which renders this form of engine best adapted for machinery where the greatest nicety and constancy of speed are necessary, as in spinning fibres and weaving fabrics.

Improvements have been made of late years in these as in other engines by the arrangement of valves for



HORIZONTAL ENGINE.

economizing steam, and by careful proportions adopted to ensure the proper balancing of the different parts. In well-made engines, having governors skilfully adjusted, the friction is reduced to a minimum, and smoothness of motion obtained. Condensing engines of this class were till lately worked at a low pressure of steam, and were considered chiefly valuable for the atmospheric force obtained in them. Now, however, it is found that the same economical employment of high pressure steam as in non-condensing engines is to be preferred, and it is therefore generally adopted, and the steam worked expansively.

Patterns of different sizes, from seven to sixty horse-power, are kept in stock by Andw. Handyside & Co., the cost of an engine varying according to the special requirements of each case, the price per horse-power decreasing as the size increases. The cost of properly fixing and starting a beam condensing engine, with boilers, may be taken as an addition of about ten per cent. on the price. For forty years engines of this sort have been made at the Britannia Iron Works, for working silk, cotton, and saw mills, in the Midland Counties, and for other purposes in all parts of the country.

Non-condensing beam engines possess the same regular motion as condensing engines, cost less money, but consume more fuel.

HORIZONTAL ENGINES

THE Horizontal High Pressure Engine, of which that shown in engraving on preceding page may be taken as a type, is the kind now most in use, and possesses the following advantages. It is direct acting, and has few working parts. It is simple in its action, and not likely to get out of order, and it is easily accessible for repairs, if necessary. It is compact, and lies low, thus avoiding the "top heavy" shaking strains to which all engines of a vertical kind are more or less liable. It gives great power in small space, and can be easily erected on a brick or stone bed, or on two sills of timber. It is the cheapest kind of engine.

The prices given on the list are for engines strongly made and well finished. The bed plate is in one piece of cast iron, to which are fastened by strong bolts and keys, the cylinder, guides, and plummer block. The piston is metallic of improved construction, the valve gearing, piston rods, and connecting rods, are of polished wrought iron, and the fly wheel shaft is of wrought iron, turned, and the fly wheel is bored so as to fit accurately upon it. Large wheels are made in two pieces for convenience in export. Each engine is fitted with governors and throttle valve, and a feed pump for the boiler is worked by an eccentric from the crank shaft; but, if preferred, this pump can be attached to the engine bed, and worked from the piston cross head.

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The boilers given in the list are of the Cornish kind, of a size suited to the respective power of each engine, and made in the best manner, as described under the head of boilers. The fittings included in price list comprise furnace mouths, bars and bearers, steam, stop, safety, and feed valves, damper and frame, blow-off cock, test cocks and glass water gauge, and a set of stoking tools. These engines can be adapted for any kind of work, and when fitted with the link motion are admirably suited for winding from mines, and for all purposes where reversing gear is necessary. Andw. Handyside & Co. strongly recommend these engines in preference to what are known as portable engines, except in those cases where constant moving from place to place is necessary. The portable engines have been made in great numbers during the last twenty years, and have, in situations where no other engine could be used, done good service, but they have often been misapplied, and have the following defects. The engine, and all its working parts, including a heavy fly wheel, are attached to the shell of the boiler, and however well made, shake while working, and thus add greatly to the wear and tear of all the parts. The tubular boiler being the part of the machine most likely to get out of order, and to need repairs and renewals, may render useless the engine attached to it, which itself may be in good order. The whole machine being thus connected together, is large, heavy, and inconvenient for shipment. Portable engines, with tubular boilers, are not so easily examined as horizontal engines, and are more liable to explosion. If it be undesirable to have brickwork, the horizontal engine can be supplied with a portable boiler complete in itself, but *separate from the engine*, and the brick or timber support necessary for the engine will soon repay the slight cost of its construction in the increased solidity and efficiency it gives in the permanent working of the engine. It is no exaggeration to say that one horizontal engine would sruvive three or four portable engines of the same class; and this may be confirmed by the statement that large numbers of the portable engines sent abroad to the colonies and elsewhere during the last fifteen years, after having caused endless trouble and expense in repairs, are now being replaced by engines, which, costing less money, last longer, and are more efficient.

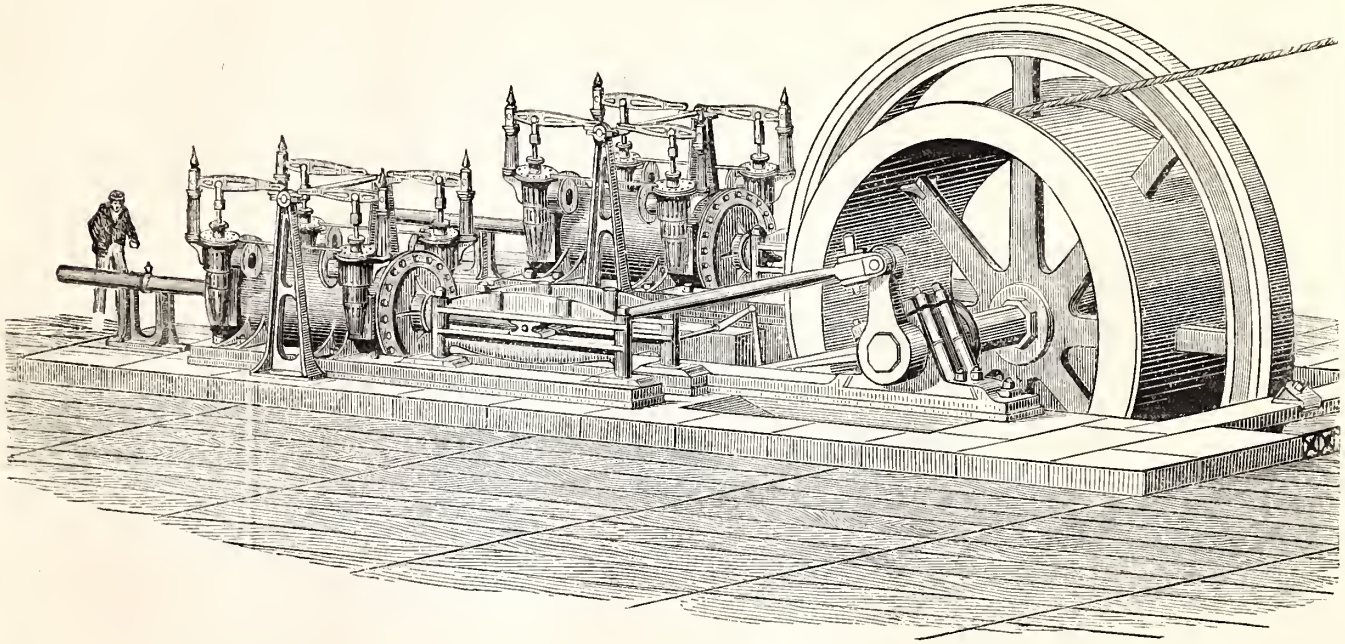
Prices of High Pressure Non-condensing Horizontal Steam Engines.

	7 H. P.	10 H. P.	12 H. P.	15 H. P.	20 H. P.	25 H. P.	30 H. P.	40 H. P.	50 H. P.	60 H. P.
Engines only ..... £	98 0 0	120 0 0	140 0 0	175 0 0	222 0 0	277 0 0	328 0 0	410 0 0	506 0 0	580 0 0
Boilers and Fittings	92 0 0	106 0 0	126 0 0	138 0 0	164 0 0	184 0 0	205 0 0	261 0 0	350 0 0	390 0 0
COMPLETE	190 0 0	226 0 0	266 0 0	313 0 0	386 0 0	461 0 0	533 0 0	671 0 0	856 0 0	970 0 0
Link motion Reversing Gear, extra.....	13 0 0	16 0 0	19 10 0	22 0 0	27 0 0	27 0 0	30 0 0	38 0 0	44 0 0	49 0 0
Expansion Valves, extra	11 0 0	15 0 0	17 0 0	20 0 0	24 0 0	24 0 0	28 0 0	32 0 0	39 0 0	44 0 0
Handyside's Patent Feed Water Heater .	11 0 0	11 0 0	11 0 0	11 0 0	16 10 0	16 10 0	16 10 0	22 0 0	27 10 0	27 10 0
Double Crank and extra Plummer Block	16 10 0	22 0 0	22 0 0	27 10 0	32 10 0	38 0 0	41 0 0	49 0 0	60 0 0	63 0 0
Approximate weight of Engines without Packing Cases	cwt. qr. lbs. 40 0 0	tons cwt. 2 6	tons cwt. 4 2	tons cwt. 5 4	tons cwt. 6 4	tons cwt. 8 6	tons cwt. 12 10	tons cwt. 14 2	tons cwt. 17 10	tons cwt. 21 10
Ditto ditto including Cases	43 0 0	2 10	4 8	5 10	6 12	8 16	13 2	14 14	18 3	22 4
Ditto ditto of Boilers and Fittings	68 0 0	3 16	4 18	5 6	6 10	7 6	8 15	10 18	14 12	17 0
Approximate measurement of Engines when packed	140 ft. cube	190 ft. cube	215 ft. cube	300 ft. cube	520 ft. cube	590 ft. cube	660 ft. cube	760 ft. cube	840 ft. cube	968 ft. cube
Approximate dimensions of Boilers	12×4.4	14×4.9	15×5.0	16×5.4	20×5.9	22×6.0	24×6.3	27×6.6	2 boilers ea. 22×6.0	2 boilers ea. 24×6.3

Packing for Export costs 3 per cent. extra.

WINDING ENGINES.

THE Britannia Iron Works are situated in the centre of the English mining district, and Andw. Handyside & Co. construct the engines and machinery for many of the large coal and iron mines. For winding from the pits, beam engines were at one time generally used, and even now some of them may be seen at work in different places. They were to a large extent superseded by direct acting vertical engines, but expensive buildings are required for these, and it has been found by the experience of late years that the horizontal direct acting engine is the cheapest

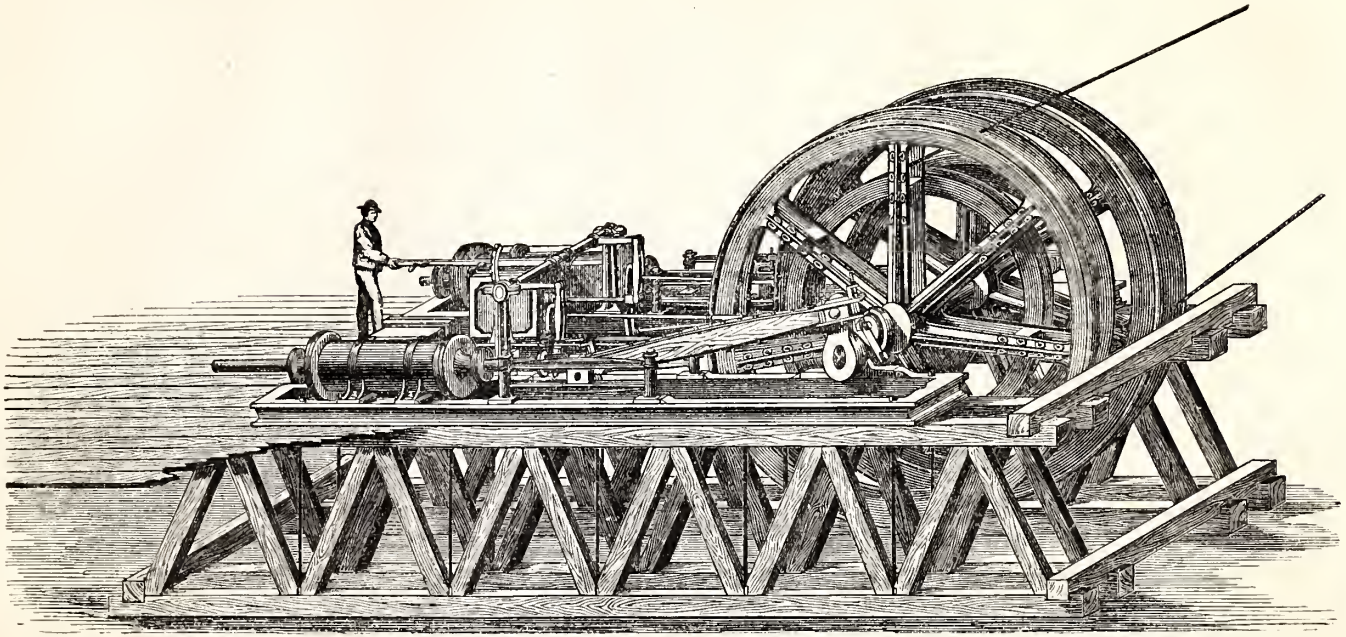


WINDING ENGINES, MOIRA COLLIERY, LEICESTERSHIRE.

H 2

and most efficient, and it is now the kind generally used for winding from the pits and up railway inclines. The sizes of the engines generally used for these purposes are those from 25 to 60 horse power, having cylinders from 16 ins. to 30 ins. diameter. Where greater power is required, two engines are generally coupled together. It is necessary that winding engines be of great strength, so that they may be able to work at high speed, and start and stop frequently and suddenly without risk of breakage. The greatest care is necessary in the manufacture of these engines, as the lives of the miners depend so much on their efficiency. The winding drums are generally placed on the crank shaft, and their size is determined by the height and speed of lift. The engines are not fitted with governors, as the safe working depends on the continual and active attendance of the engine man. In collieries, as at present worked, immense quantities of coal have to be lifted from one shaft every working day, and engines are required of corresponding strength and capacity. The break forms one of the special features of a winding engine, as by its means the engine can be stopped at the exact moment required. The importance of this may be estimated from the fact that one stroke too much of the engine involves overwinding that may be fatal to the men who are being brought up from the mine.

As a modern example of winding engines, a pair recently constructed by Andw. Handyside & Co., for the Moira Colliery, Leicestershire, are shown in the engraving on preceding page. These engines were illustrated and described in the "Engineer," of December 6th, 1867. The pit shaft is about 900 feet deep, and a box of coal, weighing 36 cwt., is drawn up in 40 seconds by the engines, which are horizontal and non-condensing, and are coupled to one crank shaft. The cylinders are 30 ins. diameter, making a stroke of 5 feet, and together exert a combined force equal to about 150 horses. The fly wheel is 18 feet in diameter, weighing about 8 tons, and to this wheel is applied a break of a new and improved form. It is arranged in connection with a small steam cylinder, that while at ordinary times it can be worked in the usual manner by the foot of the engine man, it can also in moments of emergency receive the full power of the steam and stop the engine even when at full speed. This is a most valuable addition to the safety and efficiency of a winding engine. The drum for the winding rope is fixed on the crank shaft, and as one rope is



WINDING ENGINE ON TIMBER FRAMING.

wound up, another on the opposite side of the drum is unwound. These engines are supplied with steam by four boilers, 36 feet long, and 5 feet diameter. The engines complete, as described above, would cost from £1,600 to £1,800, including winding drum and *fixing*, and the boilers and fittings from £800 to £900, depending on the quantity of piping and other circumstances. The total weight of engines is about 50 tons.

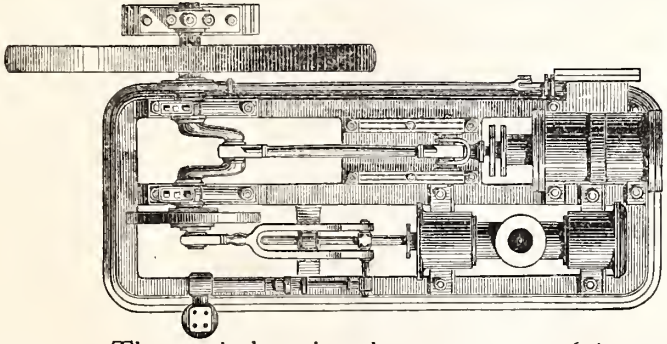
To obtain an approximate idea of the cost of a winding engine, from £3 to £5 per horse-power may be added to the prices of horizontal engines, given on page 50. Sometimes the same engine winds and pumps also, a second motion shaft generally conveying the power for the latter purpose. Mining engines of the kind described here, and constructed by Andw. Handyside & Co., are at work in large numbers at the collieries and iron-stone pits in Derbyshire, Nottinghamshire, Leicestershire, and Staffordshire.

The illustration on page 53 shows a pair of winding engines supported on timber framing. This plan is adopted in places where it is difficult to procure the ordinary building materials of stone and brick, and in places where the land is so soft or marshy as to render a stone foundation expensive or insecure. Under these circumstances a properly-constructed framework of timber offers a convenient bed on which the engines can be fixed. This method of erecting pumping and winding machinery is efficient and economical. It is so, too, for mines where the quantity of minerals is small or uncertain, as the framework is erected quickly in the first instance, and can afterwards be taken down and removed with the machinery to another mine. When engines are manufactured for erection in this way, a drawing showing the best mode of framing the timber is supplied with them.

PUMPING ENGINES.

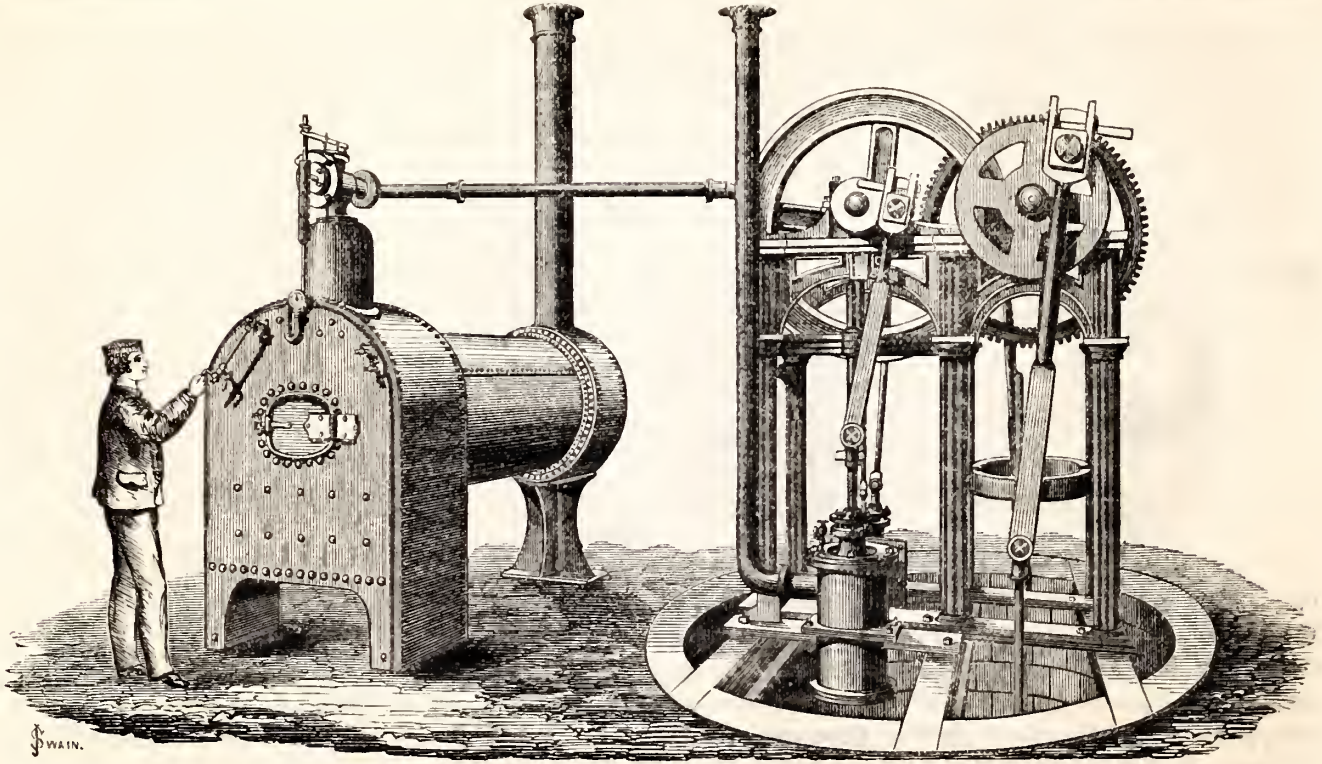
THERE are more kinds of pumps and of pumping engines made than it is possible to describe here. Andw. Handyside & Co. construct them for many different purposes. The illustration shows a very simple and efficient engine suitable for paper mills, breweries, dye works, or other works, where a constant supply of water has to be raised to a moderate height. It is also very useful for raising water to supply locomotives at railway stations.

The engine and pump are fixed on one bed-plate, and can easily be removed and re-fixed if required. They are so arranged that the entire power of the engine can be applied to the pump, or the latter can at any time be disconnected from the engine, and the power applied to other purposes. The pump is double acting, discharging a continuous stream of water, and it is made either of iron or brass, the latter material being generally preferred in breweries. An engine of this kind was constructed by Andw. Handyside & Co. for Messrs. Allsopp & Sons' brewery, at Burton-on-Trent, where it raises the water used in brewing from a depth of 25 feet. It can also be used for pumping wort.



One of these engines, six horse power, will raise 6,000 gallons of water 40 feet high in an hour, or 5,000 gallons 60 feet high. If made with an iron pump, the price is £192, or with a brass pump, £215. An engine of ten horse power will raise 10,000 gallons of water 40 feet high in an hour, and the price with iron pump is £290, or with brass pump £322. These prices do not include boilers, the cost of which is given in list on page 50. Pumping engines of this description are made up to 30 horse power.

The vertical engine shown on page 56 is made by Andw. Handyside & Co. for raising water directly from a well. It is all fixed on one strong bed-plate, which rests upon iron beams placed across the well. The pumps rest upon iron beams in the well. They supply a constant flow of water, and are arranged so that the weights of the ascending and descending pump rods shall balance each other. These engines are of eight horse power, and are adapted for pumping from wells not exceeding 120 feet in depth. They can raise to the surface and deliver into a tank, about 25 feet high, from 4,000 to 5,000 gallons an hour, and cost £255, and £25 in addition if the pumps are of brass. A "Cornish" boiler, costing with mountings £68, can be used, or a tubular boiler, as shown in the

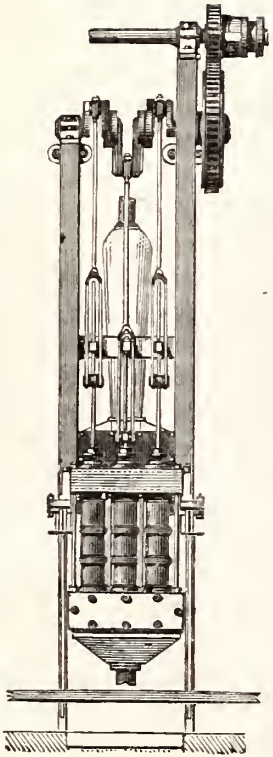


PUMPING ENGINE.

illustration, costing £104. The total weight of engine, pumps, and boiler, complete, is about 10 tons, and if packed for shipment the cases cost £9 10s. extra. Andw. Handyside & Co. have recently sent a number of these engines to India for pumping water at railway stations for the use of locomotives. Where the well is sunk in sandy or other loose soil, a wrought-iron framework for supporting the masonry is generally used. This costs from £60 to £90, according to depth of well, &c.

MINING PUMPS.

PUMPS for Mines are of a special character, and generally of great strength, requiring considerable power to work them. Both lifting and forcing pumps are used, and often in combination, for in deep mines it is impossible to raise the water by one set of pumps, as the column of water would be so heavy that it would force its way through the joints of the rising main. This will be apparent when it is remembered that water has sometimes to be raised from a depth of 200 fathoms, or 1,200 feet. Andw. Handyside & Co. construct pumping apparatus for many of the coal and iron mines in the Midland Counties, and generally use the non-condensing horizontal engine for the purpose. The pumps are usually driven from a separate shaft, working at a much less speed than the engine. If the pit be of considerable depth, reservoirs are formed for the water at different levels, and it is raised by a series of successive lifts by different pumps. Great care is necessary in the arrangement of the pump rods, so that their weight may as much as possible counterbalance. Sometimes the same engine both pumps and winds, but where a large quantity of water has to be constantly raised from a mine, it is better to have an engine for this purpose alone. It is impossible to state the cost for apparatus so variable, but one example may be given. For raising 20,000 gallons per hour from a depth of 300 feet, an engine would be required of 20 horse power. The price of this, with boiler, as given on page 50, is £386. In addition to this sum, the price for shafting, gearing, pumps, and pipes, necessary to complete the whole, would be from £340 to £390. Andw. Handyside & Co. are glad to suggest the best arrangement for pumping, and to give estimates of cost, when necessary particulars are supplied to them.



THREE-THROW PUMPS.

THE "three-throw pump," shown in the engraving, is used for raising water to moderate heights, and in breweries it is used either for pumping water or wort. The three cranks are set at equi-distant angles, so that there is a continuous flow of water. The pumps are driven by a spur wheel, which is connected by shafting to a steam engine; about four horse power being required to work the pump.

A pump of this description, having three working barrels 6 ins. diameter, and with cast-iron valve boxes, costs £175. If made with working barrels 5 ins. diameter, and with all the parts that come in contact with the water made of brass, and having a copper air vessel, the price would be £280. Pumps of this kind will raise about 15,000 gallons of water 40 feet high per hour. The weight is about $4\frac{1}{2}$ tons.

BOILERS.

THE advantages of high-pressure steam are becoming so apparent, and its use so general, that boilers of corresponding strength are needed. Good iron should in all cases be used, and its working strain should bear a much less proportion to its ultimate endurance than is necessary in girders. For the parts of the boiler immediately over the furnace, plates of exceptionally high quality should be employed, and Lowmoor or similar iron is generally used. Owing to the elaborate process by which this class of iron is made, there is the least possible risk of hidden blisters, or other defects. In all boilers made by And^{w} Handyside & Co. this precaution is taken.

The cylindrical shape of a boiler gives it an immense power of resistance to the pressure within it, and when this form is in any part of the boiler departed from, the greatest care is necessary to give the requisite strength. This is obtained by the use of stays, in number sufficient for the purpose; and on the skilful disposition of these the safety of the structure mainly depends, especially in large boilers, and wherever flat surfaces are exposed to the force of the steam, or the action of the fire. The boilers enumerated here are constructed for burning coal, but the furnaces can be arranged for wood or other fuel, and in most cases without extra cost.

For the safe and efficient working of boilers, the principal points to be observed are, that the safety valves be made of sufficient capacity, and kept clean to prevent their sticking, and that the feed water be admitted regularly and equably. The boilers made by And^{w}. Handyside & Co. can be safely worked up to 50 lbs. pressure per square inch, and they are in all cases tested to 100 lbs.

The simplest of all boilers is a plain cylinder with hemispherical ends, which is built into brickwork, with the furnace beneath, and so arranged that the flues shall heat all the surface up to the water line. As, however, these boilers are the slowest in raising steam, and consume a large quantity of fuel, they are seldom used now except at collieries and places where waste coal is burnt, and where its cost is inappreciable. They are rather less liable to burning and to accidents than those of a more complicated form, and are generally made from 4 feet to 6 feet in diameter, and from 20 feet to 40 feet in length. They cost from £17 to £20 per ton, and can easily be fixed by an ordinary bricklayer.

One of the earliest improvements in steam generators was the Cornish boiler, which still bears the same name, and is at the present time more used for stationary engines than any other kind. Of a cylindrical form, with flat ends, it has within it one or two smaller cylinders parallel to its length, forming the furnace, which is thus surrounded by water, and gives out its first and greatest heat to advantage. Up to 4 feet 6 ins. diameter, there is space for only one inner tube; beyond this, and up to 7 feet (the greatest diameter expedient), two tubes are generally used. For steady everyday work these boilers are the simplest and best. They are built into brickwork, so that the

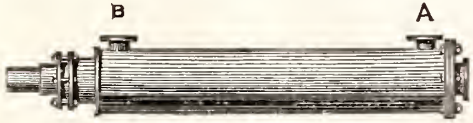
flames and heated vapours after leaving the tubes pass around and under the whole surface below the water level. With proper arrangement of safety valves, and with ordinary care in stoking, they are durable, and free from risk. These boilers cost from £19 to £23 per ton, and are named in the list of prices on page 50.

Tubular boilers are now used to a large extent where skilled labour for fixing is expensive, and where brickwork is inconvenient. They consume less fuel than Cornish boilers. They are complete in themselves, no brickwork being needed; and the flames passing from the fire-box through a number of small tubes inserted in the water space, a very large surface is exposed to the intensest heat of the fire. They are made either vertical or horizontal. They raise steam very quickly, and need not be of so great a size as the Cornish boilers. They, however, involve more wear and tear, need repairs oftener than the simpler kinds, and do not last so long. They are used in locomotives, marine and portable engines, and for situations where fuel is expensive. They cost from £30 to £50 per ton, according to their shape, the quality of iron, and the number and material of the tubes. They are seldom made for stationary engines beyond 25 horse power, but beyond that power two boilers can be used. Portable tubular boilers, including mountings, cost:—7 H. P., £103; 10 H. P., £130; 12 H. P., £154; 15 H. P., £185.

HANDYSIDE'S FEED-WATER HEATER.

IN non-condensing engines the exhaust or waste steam may be advantageously used to heat the water for the boiler.

The apparatus shown here was designed by Andw. Handyside, in 1861, as an improvement on the methods then existing. The object desired is to withdraw from the exhaust steam the greatest amount of heat, and to convey it directly or indirectly to the water. In many of the plans that have been adopted for raising the temperature of the water by the use of the exhaust steam, the free escape of the steam has been obstructed, causing a back pressure on the piston, and consequent loss of power in the



engine. This is avoided by the plan adopted by Andw. Handyside & Co., while the water is heated to the greatest advantage. Two tubes are arranged, one within the other, and the steam passes through the inner chamber, which is so contrived that the heated vapour impinges most effectually on the iron, and then escapes into the open air. The water from the feed pump of the engine passes into the heater at A, enters the annular space between the inner and outer tubes, and is then forced in a spiral direction over a large surface, absorbing the heat as it passes, and is then discharged at B to the boiler. By means of this apparatus the temperature of the water can be raised from 40° to 180°. The consequent saving in fuel is very great, and speedily repays the cost of the heater, which occupies little space, and can be placed beneath the floor in the engine or boiler house. The heaters are made of various sizes, from 4 feet to 10 feet in length, at the prices given in list on page 50.

MACHINERY.

ANDW. HANDYSIDE & Co., having the usual resources of a large engineering factory, manufacture machinery for many different purposes. The foundry, boiler and smiths' shops, and the most modern machine tools enable them to carry out the processes of mechanical construction speedily and on a large scale.

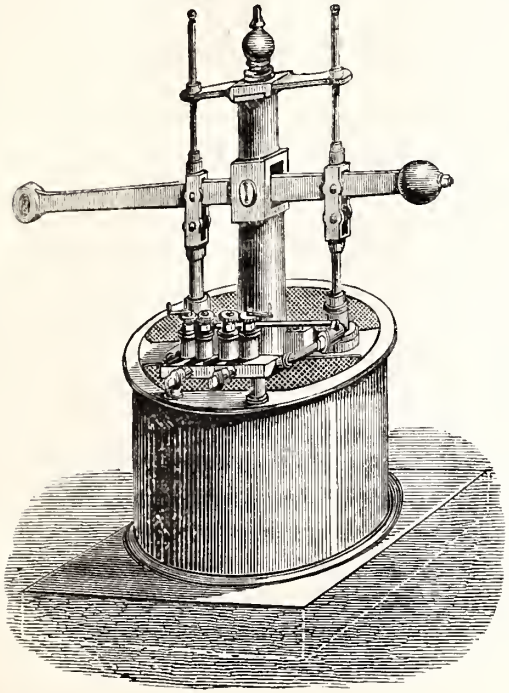
Situated in the centre of a manufacturing district, where silk, cotton, paper, and saw mills are established in large numbers, they constantly construct the many different varieties of millwright work. Upwards of 1,200 spur and bevel wheel patterns are registered, and kept ready for use. The machinery necessary for breweries is regularly manufactured, and the large breweries at Burton-on-Trent afford constant employment in this special branch of engineering. At the large new brewery recently erected by Messrs. Allsopp & Son at Burton, Andw. Handyside & Co. constructed the engines, pumps, hoists, hop presses, and other machinery.

Many different machines are enumerated here, but beside these, the manufacture of machinery and apparatus for special purposes will be readily undertaken.

HYDRAULIC MACHINES.

THE system of hydraulic machines, inaugurated by Bramah, was rendered complete by his invention of packing-leathers, for keeping the joints and moving parts tight enough to resist the pressure of the water. Wherever great pressure is needed for the different processes of manufactures, the hydraulic ram can give it to a degree far beyond any other apparatus. Although theoretically there is hardly any limit to the pressure that can be exerted by this means, in practice from 1,500 to 2,500 lbs. per square inch is the extent to which it is usually applied on the ram. For exceptional cases, a pressure of more than two tons per inch is obtained, but it is seldom that so great a

force is required. The first-named degree of pressure obviously affords very great power with machines of moderate size. There are many matters which require careful attention in these machines, and render their manufacture a special branch of engineering.



HYDRAULIC PUMPS.

ANDW. HANDYSIDE & Co. manufacture these of different sizes and capacities for the various hydraulic machines enumerated here. The greatest accuracy is given to the construction of the valves and other working parts to keep them tight and efficient, and the pump boxes, plungers, and valves are made entirely of brass, to prevent rust when not in use. The smallest pump, No. 1, has one plunger $\frac{3}{4}$ inch diameter, this being the size most convenient for working by hand, although it can if needed be driven by steam power. A pump of this kind, fixed on a circular water tank two feet diameter, costs £33, and is adapted for testing presses, small packing and hop presses, tyre-blocking, axle-forcing, and other machines. The weight is about 5 cwt. A duplicate set of packing-leathers is supplied for £1 10s.

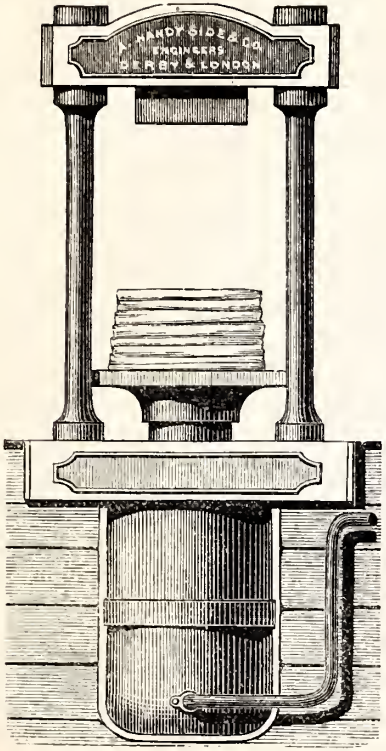
The double pump shown in engraving is strong and efficient, and can be used to advantage with most hydraulic machines. It has two plungers, one being two inches diameter and the other one inch diameter. By this arrangement the first and easiest pumping in each operation is performed speedily by the two plungers rising and falling alternately, and when the final and intense pressure has to be applied,

the larger pump by a self-acting motion is disengaged and the smaller one finishes the operation by itself. These pumps are generally driven by steam power, and the working lever is prepared with a view to this. They are fitted on circular tanks 3 feet 2 ins. diameter. The price is £60, and if reversing valves are supplied, as is necessary for double acting presses, the price is £20 extra. The total weight is about 12 cwt. Duplicate packing-leathers, £3 10s. per set extra.

And^{w}. Handyside & Co. make a quadruple pump, which is extremely powerful, and which can be used for the heaviest service to which hydraulic machinery is applied. The pumps are fixed on a rectangular tank 3 feet long and 1 foot 4 ins. wide. Four pumps, three of them having plungers 2 ins. diameter, are worked from the main shaft by eccentrics, which are set at different angles. The action of the three pumps is very rapid, and when they have forced the hydraulic ram three-fourths of its stroke, the pump with smaller plunger finishes the operation, as described in the double pumps. These pumps cannot be driven by hand, and the counter shaft is fitted with a pulley for attachment to existing machinery. Pumps of this kind are most efficient for linseed-oil mills, or wherever the work to be performed is constant and severe. The price for the complete set is £160, and the weight about 22 cwt. Duplicate packing-leathers, £6 per set extra.

COTTON GINNING MACHINERY.

AND^{w}. HANDYSIDE & Co. can supply the whole apparatus necessary for a ginning factory. They make the iron buildings, the engines and boilers, and arrange the shafting and gearing to suit the machines required. Cotton gins of many kinds are adapted by their inventors for different varieties of cotton, and And^{w}. Handyside & Co. will supply the special machines needed in any case. Estimates and plans will be furnished in accordance with instructions supplied to them.



HYDRAULIC PACKING PRESS.

THE press shown in engraving is made by Andw. Handyside & Co. for compressing paper or other substances. This hydraulic machine is much more simple, and exerts far greater force than the ordinary screw or lever presses. They can be made of any size. No. 1 has a ram 6 ins. diameter, and a table 24 ins. square, with a space 36 ins. high. The weight of this press is about 60 cwt., and the price £93, or complete with No. 1 hand pump, £125. Duplicate packing leathers, £4 per set extra.

No. 2 is a larger size, having a ram 8 ins. diameter, a table 36 ins. square, with an opening 48 ins. high. This press weighs about 90 cwt., and costs £120. The No. 1 hand pump can be used with this, but if the press is to be worked constantly, and steam power can be obtained, the double pump described on page 63 will be more speedy and efficient.

HYDRAULIC TESTING PRESS.

A SMALL hydraulic testing press, having a ram 7 ins. diameter, capable of testing to 100 tons, and complete with No. 1 pump, costs £60, the weight being about 35 cwt.

THE ACCUMULATOR COTTON PRESS.

THE Accumulator Cotton Press is the invention of Mr. George Ashcroft, and it embodies all the valuable features of his several patents. It possesses the following advantages:

Great power, so that it can subject a bale of cotton to enormous pressure.

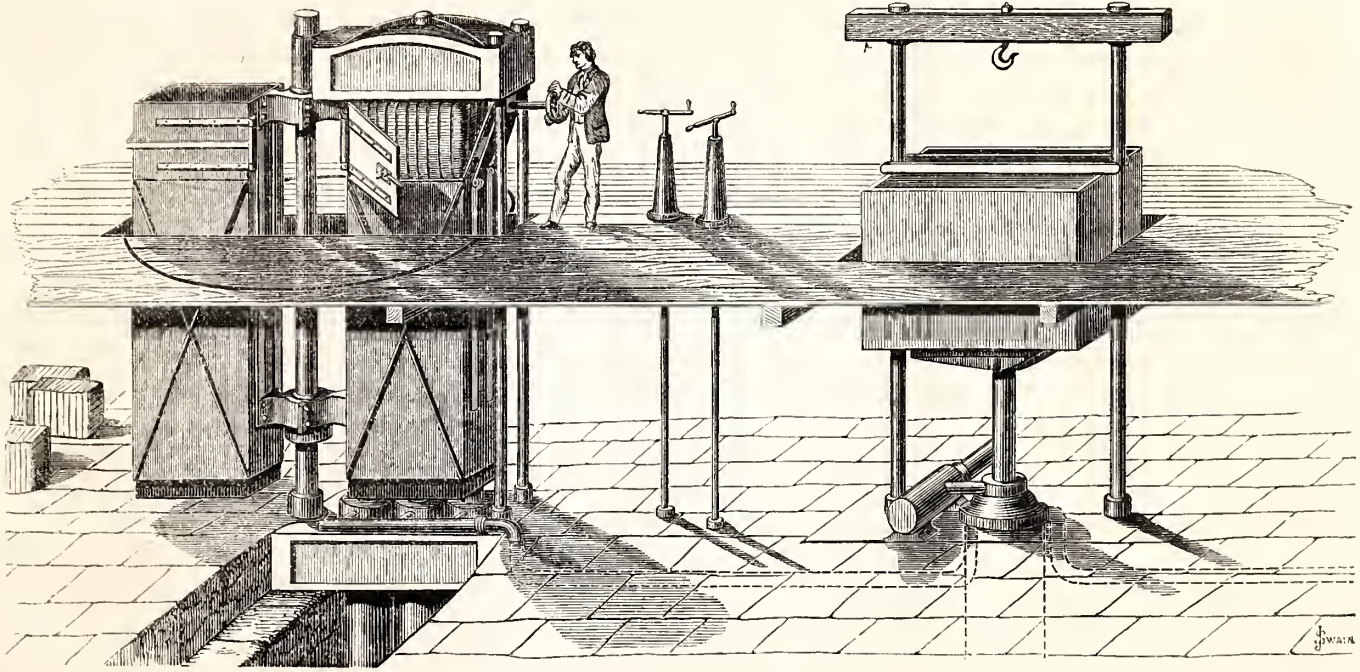
Speed, so that 25 bales may be easily packed and hooped per hour.

In all other presses hitherto contrived it has been impossible to combine the greatest power with sufficient speed. The combined screw and lever presses are limited in their power, and are subject to excessive wear and tear on the screws and parts through which the power is conveyed to the bale. The ordinary hydraulic machines are slow in action. The Accumulator Press is designed on a system which has been successfully applied to cranes and hoists, where speed is essential, and it exerts the maximum power practically attainable by hydraulic or any other pressure. Instead of the usual slow process by pumping, the constant pressure which is always maintained in the accumulator is conveyed immediately to the ram, which it forces up in a few seconds.

The machine has two boxes, which by an ingenious arrangement revolve, so that while one bale is being pressed the second box is being filled with cotton, and on the completion of the first bale, the boxes change places, the second bale coming at once under the action of the ram. By this means considerable time is saved, the press being constantly employed. The engraving shews the door of the box open, with a bale finished and hooped.

By the use of the Accumulator Press 30 lbs. of cotton to each cubic foot can be compressed and held in the hoops—a bale 4 feet × 1 foot 9 ins. × 2 feet 6 ins., weighing when shipped 520 lbs. This is a much greater quantity than can be obtained by any other press, and the saving in freight is obvious.

And^{w}. Handyside & Co. manufacture these presses, and can refer to some which are now in successful operation. The complete apparatus consists of steam engine, boiler, pumps, press, and accumulator. A small quantity of woodwork is also required.



THE ACCUMULATOR COTTON PRESS.

HYDRAULIC HOP PRESS.

THE annexed engraving shows the hydraulic press manufactured by Andw. Handyside & Co., for use in breweries. It effects a considerable saving in hops by expressing liquor that would otherwise be wasted; and also by its use a weaker but valuable liquor may be obtained after a second boiling. An enormous pressure may be applied to the hops, and the result far exceeds that produced by any other means.

A. is a strong cast-iron box, having a lining of copper or tinned iron, perforated with small holes. The wet hops after having been used are thrown into the box, and the ram B. rising, forces up the plate C. and squeezes the liquor through the perforated lining into the vertical grooves, shown in sectional plan. The liquor escapes through a brass tap at bottom of press. The lid D. is kept tightly closed during the pressure by the bolts E. By only half a turn of the nuts F. these bolts can be released and drawn out sideways, the lid having a balance weight to facilitate its movements. When the lid is opened the movement of the ram is continued, and the hard pressed hops are pressed out into a truck or wheelbarrow. The hops, instead of being wet and cumbersome like ordinary refuse hops, leave the press in a hard compact mass, easy of transport, and so dry that they can be used for stable litter instead of straw.

The pumps for these presses can be worked either by hand or steam power. The presses are made of four sizes. Nos. 1, 2, and 3 are round in shape as illustrated, and No. 4 is rectangular, like the packing press shown on page 65, and is the kind made for Messrs. Allsopp's new brewery, Burton-on-Trent.

No.	Size of Box.	Depth of Box.	With Copper Lining.	With Galvanized Iron Lining.	Approximate Weight.	Quantity of Hops, (weighed when dry.)
	dia.		£. s. d.	£ s. d.	cwts.	cwt.
1	1 ft. 8 ins.	2 ft.	73 0 0	69 0 0	40	$\frac{1}{2}$
2	2 ft.	2 ft. 6 ins.	128 0 0	122 0 0	90	1
3	2 ft. 10 ins.	2 ft.	152 0 0	143 0 0	120	$1\frac{3}{4}$
4	3ft. long × 2ft. wd.	2 ft. 6 ins.	131 0 0	123 0 0	100	2

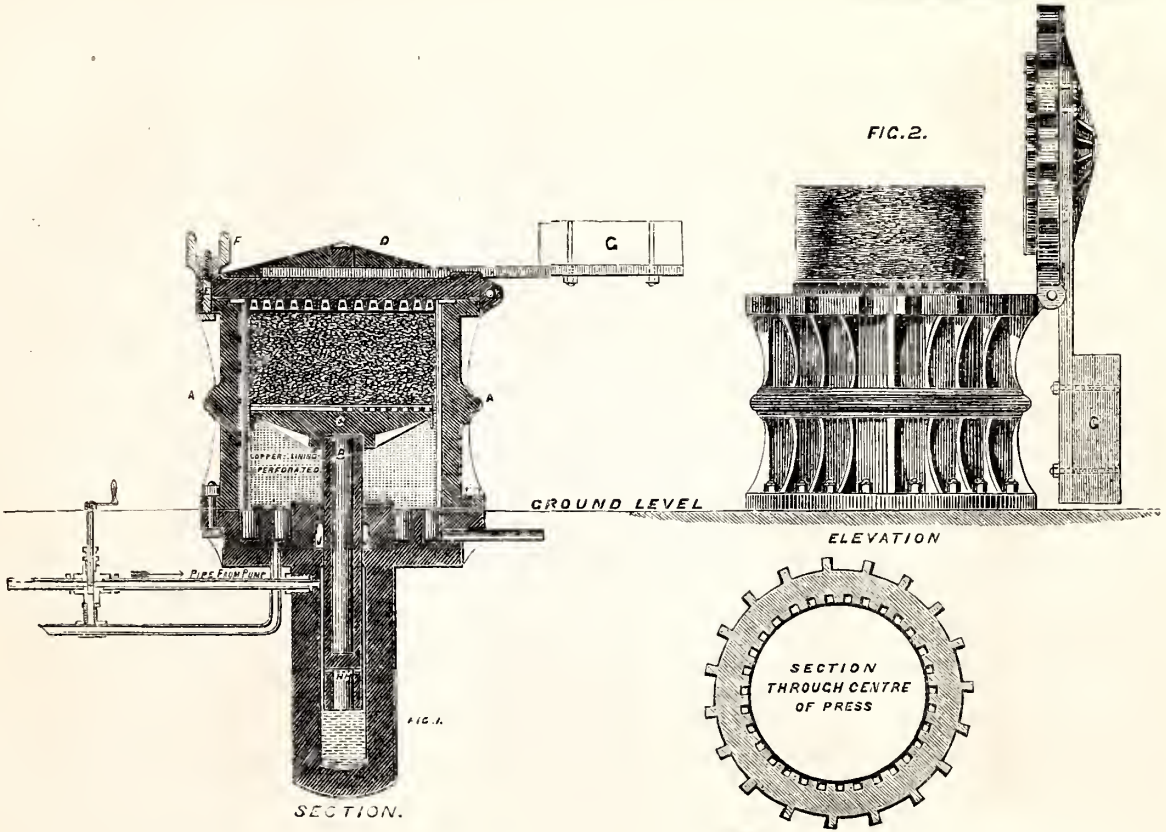
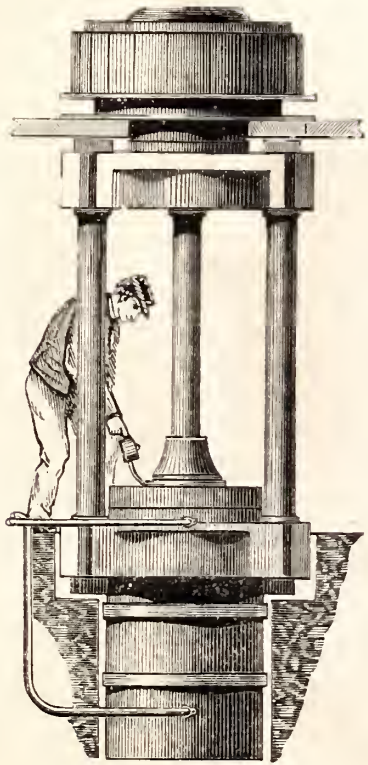
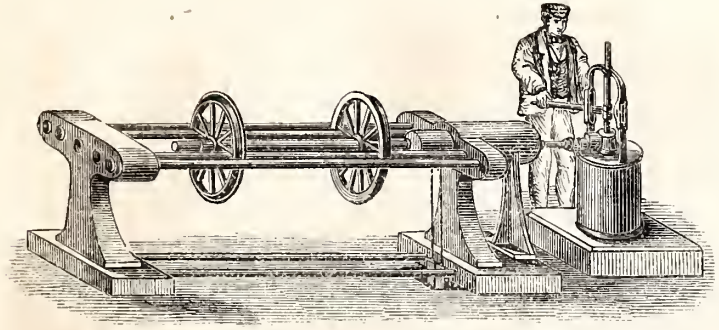


FIG.2.
F
D
G
A
A
C
B
COPPER LINING PERFORATED
GROUND LEVEL
PIPE FROM PUMP
FIG.1.
SECTION.
ELEVATION
SECTION THROUGH CENTRE OF PRESS



HYDRAULIC LEAD-PIPE MAKING MACHINE.

AMONG the many different uses to which hydraulic pressure is applied, it has probably in no case been more successful than in the manufacture of lead piping. The engraving shows a very efficient machine for this purpose, which is constructed by Andw. Handyside & Co. The press consists of the hydraulic cylinder and the container, and the pressure exerted is so enormous that special precautions have to be taken for the safe and proper use of the apparatus. The hydraulic cylinder is of immense strength, and is lined with brass to secure a very smooth surface for the cup leathers of the piston to work against, and the piston also is covered with brass. Around the lead container, at the upper part of the machine, a small fire-brick furnace is placed to keep the lead at a proper temperature. The press is double acting, and the pumps are therefore made with the necessary reversing valves. The machine is capable of making pipes either of lead or block tin, and from $\frac{1}{8}$ in. up to 6 ins. in diameter. Twenty charges of lead can be worked in a day of ten hours, each charge weighing from 1 to 2 cwt., according to the required diameter of the pipe. A separate set of steel dies is needed for each size of pipe. The price of the machine and pumps is £350, and each set of dies £10. The total weight is about 12 tons. Two lead pots, with furnace castings, cost £39. A crane for lifting lead from the pots to the container costs £27. The pumps supplied with the machine are those shown on page 63.



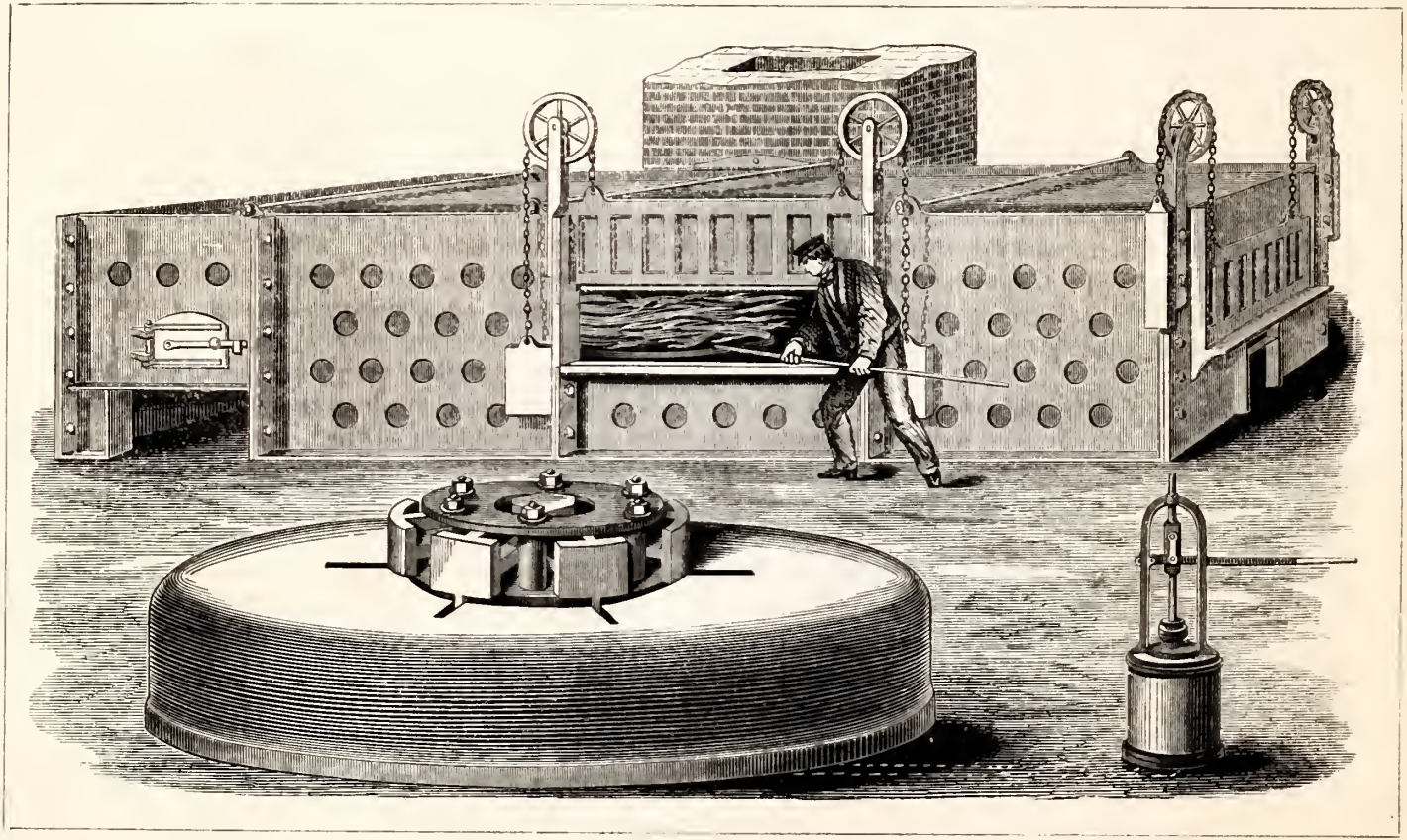
AXLE FORCING PRESS.

THE engraving shows the hydraulic machine made by And^{w}. Handyside & Co. for forcing railway wheels from their axles, and replacing them after repairs. Considerable power is necessary to effect this, and the hydraulic press performs the operation in a simple and speedy manner. The wheels are suspended on the horizontal bars, and kept in position by adjustable cotters, while the advancing ram pushes the axle out of its place. The return stroke of the ram is effected by suspended balance weights. At either end of the machine are strong cast-iron standards, and these rest upon a stone or timber bed. The pump is easily worked by one man. Axles of any gauge, having wheels of from 2 feet 6 ins. to 6 feet diameter, can be forced by this machine. The price complete with pump is £138, and the weight about 6 tons.

For large railway and wagon factories, where a considerable number of axles have to be forced, these machines are supplied with stronger framework, having cranes and travelling blocks for lifting the wheels quickly and easily into and out of place. This machine costs £400, and weighs about 20 tons.

TYRE AND PLATE FURNACE.

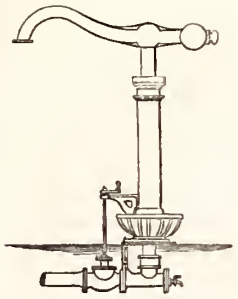
THIS furnace is constructed specially for heating railway-wheel tyres before they are blocked, and is generally used in conjunction with And^{w}. Handyside & Co.'s hydraulic blocking press. The furnace is 24 feet long, 8 feet wide, and is constructed with an outer casing of strong iron plates, within which a lining of fire-brick is placed;



and the flues are so arranged that the clearest and intensest heat shall pass over and around the tyres. The fire is maintained at the end of the furnace, and is fed with fuel through the small door shown on the left in the engraving. At the side and end large doors made of fire-brick encased in iron are hung with balance weights. Through these doors the tyres are introduced. Separate operations can be conducted at each aperture at the same time, and either tyres or plates, or both, can be heated at once. The bricks are made of fire-clay, and of a size and shape moulded especially for the furnace. Where tyres or plates of considerable size are worked, a light wrought-iron crane is used for lifting the tyres to the blocking press, or the plates to the bending rollers. The price of this crane is £32. The furnace fitted complete, and including a due supply of bricks, costs £210. A detailed working drawing is supplied with each furnace. The weight of iron is 9 tons, the number of bricks 12,000, and their weight 38 tons. The tyres when sufficiently heated are removed at once to the

HYDRAULIC BLOCKING PRESS.

THIS is shown in the engraving. The cylinders and heavy frame of the press are firmly attached to stonework below the ground, and only the table and other parts are exposed to view. The tyre is placed upon the table, and as the ram rises, the tapered hexagon top forces out the radial blocks, and the tyre is distended to a perfect circle of the required diameter. By means of a small hand pump, an enormous pressure is given to the ram, which far exceeds that obtained in the ordinary screw press. Each press is supplied with one set of radial blocks for locomotive tyres, and one for smaller carriage tyres. In ordering a machine the inner diameter of the tyres should be given. The press weighs 11 tons, the pump 6 cwt., and the whole machine costs £250.



WATER CRANES.

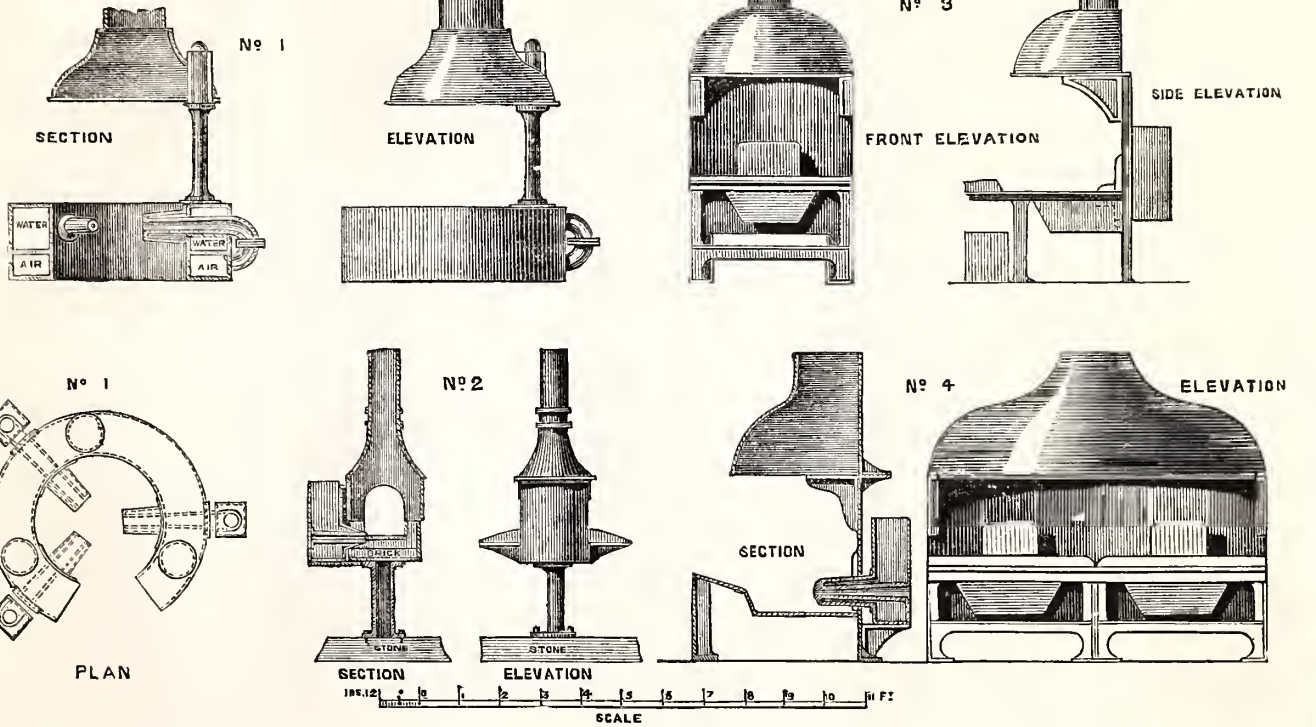
THE illustration shows the kind usually made for supplying locomotives with water. They are adapted for any gauge of railway, and can be supplied with or without stop valve and supply pipes. For climates subject to frost the fire-grate round the base is necessary. The cost varies from £28 to £35 each. One of the pumping engines shown on pages 55 or 56, and a tank as described on page 81, furnishes, with one of these cranes, the complete apparatus necessary at a railway water station.

SMITHS' HEARTHS.

MESSRS. HANDYSIDE & Co., have given special attention to the manufacture of smiths' hearths, and having by careful experiments ascertained the forms best adapted for their own work, have for many years supplied them to others.

In fitting up workshops too little attention is generally paid to the arrangement of the smiths' shop, and the rudely-contrived clumsy hearths that are often used entail frequent repairs, excessive heat in the shop, great consumption of fuel, and dirtiness. At the Royal Small Arms Factory, at Enfield, the numerous smithies are fitted with the hearths made by And^{w} Handyside & Co., and shown on the engravings. At the Royal Arsenal, Woolwich, also, and by many of the principal railway wagon builders and engineers, they are extensively used. They are generally intended and are best adapted for working with a fan blast, (but bellows can be attached if necessary). They are light and compact, and the arrangement of the fire and the chimney gives the greatest result from the fuel consumed with the minimum of heat wasted through the chimney and in the shop. All the hearths are supplied with improved water "Tuyère irons," which are preserved from burning by the water coming inside a double casing close to the fire.

SMITHS' HEARTHS, (1.)



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The prices quoted on page 78 include "Tuyères," the cisterns and troughs where shown on the engraving, and also the lining of fire-bricks in those cases where it is specified in the description given below.

No. 1 was first made for "bossing" wrought-iron wheels, and for this purpose it is especially suitable, but it is used in all cases where large lumps of iron have to be worked, the three "Tuyères" concentrating an intense heat upon the forging. As will be seen by the engraving, the fire is surrounded by water, which preserves the hearth from burning; and below this the blast is received into a chamber, from which it passes through the "Tuyères" into the fire, each "Tuyère" having a sliding shutter regulating the blast.

No. 2 is a small hearth for heating rivets, and repairing smiths' and fitters' tools. The fireplace is lined with fire-brick.

No. 3 is a size well adapted for ordinary smiths' work, and is strong and compact.

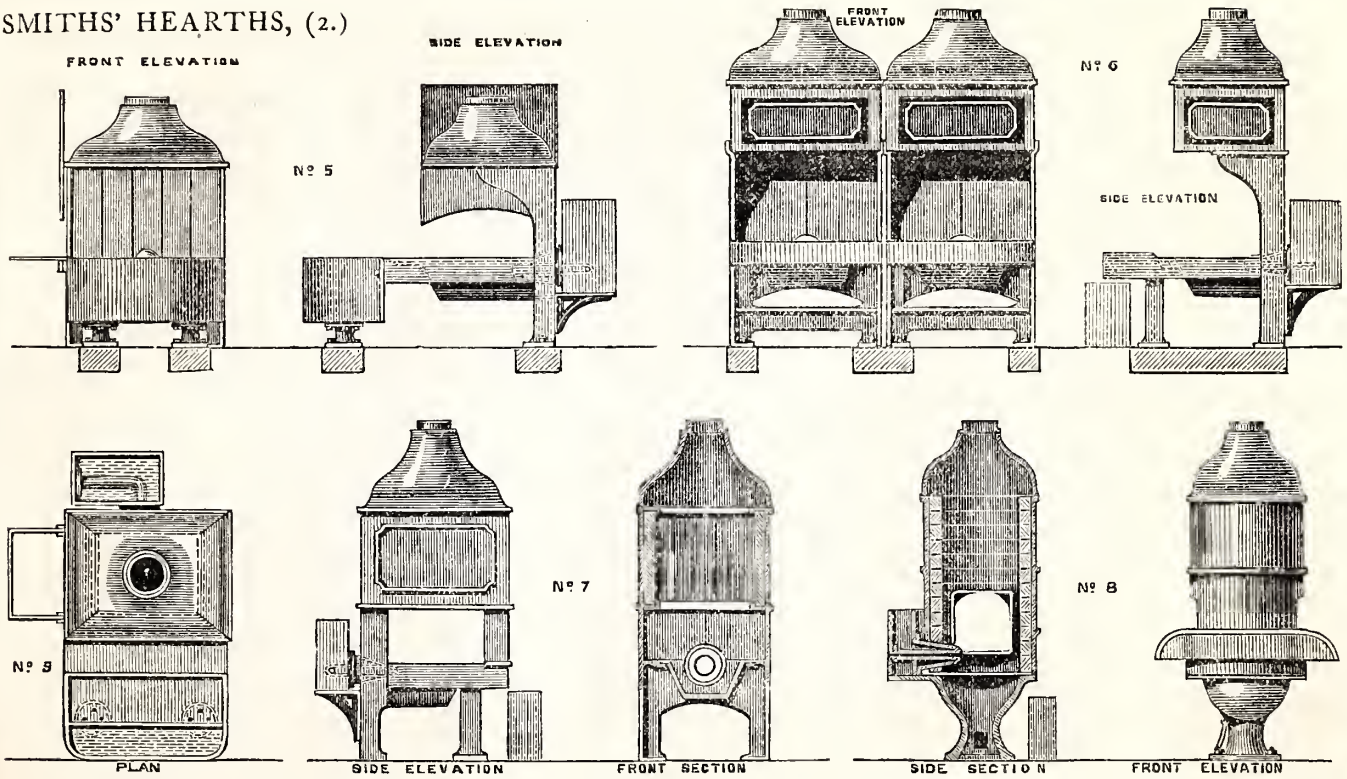
No. 4 is a double hearth, having two fires, like No. 3, under one hood and chimney, by which arrangement less space is occupied than by separate hearths.

Nos. 5 and 6 are an improvement on 3 and 4, and for general smiths' work are among the best hearths that are made. They are lined with fire-brick, and do not give out heat into the shop; and No 6 has also by the arrangement of the hood, the merit of not allowing the smoke to come out into the shop. These hearths are largely used at Enfield and Woolwich, and in the workshops of wagon builders; and in the smithies of English and foreign railway companies they have proved strong and lasting. No. 6, described above, can be used singly or in pairs; and if in the middle of a shop, four can be grouped together under one chimney pipe. The water troughs are in front, but are separate castings. These hearths are made in three sizes, as in price list.

No. 7 was specially designed for tempering steel forgings. It is lined with fire-brick, is enclosed on both sides, and the hood comes low down towards the fire.

No. 8 is a very convenient hearth for light forgings and shafting, and with a slight alteration in its form can

SMITHS' HEARTHS, (2.)



also be adapted for making bayonets, for which purpose it is used at Enfield. It is open at the sides only, and is lined with fire-brick.

All the hearths are easily fixed, or taken to pieces and removed, and if they stand on a solid floor need no brickwork or building of any kind. In large smithies the chimneys can be arranged so as to discharge into one shaft. Stand pipes are provided for the blast; they have a flange for connecting to the "main" under the floor, a valve handle within reach of the smith, and a nozzle for insertion in the "Tuyère" pipe. They are in two sizes:—No. 1 suitable for hearths Nos. 2 and 8; No. 2 for hearths 3, 4, 5, 6, and 7.

And^{w} Handyside & Co. can supply with their hearths the rotatory fans, which are the best for producing a continuous blast. If necessary, the same fan can produce a blast for both smithy fires and a foundry cupola.

When a number of hearths are required, And^{w} Handyside & Co. will be glad to supply the necessary pipes and connections for the blast, and to prepare a drawing showing the most convenient and economical arrangement for the smiths' shop and the entire apparatus.

Price List.

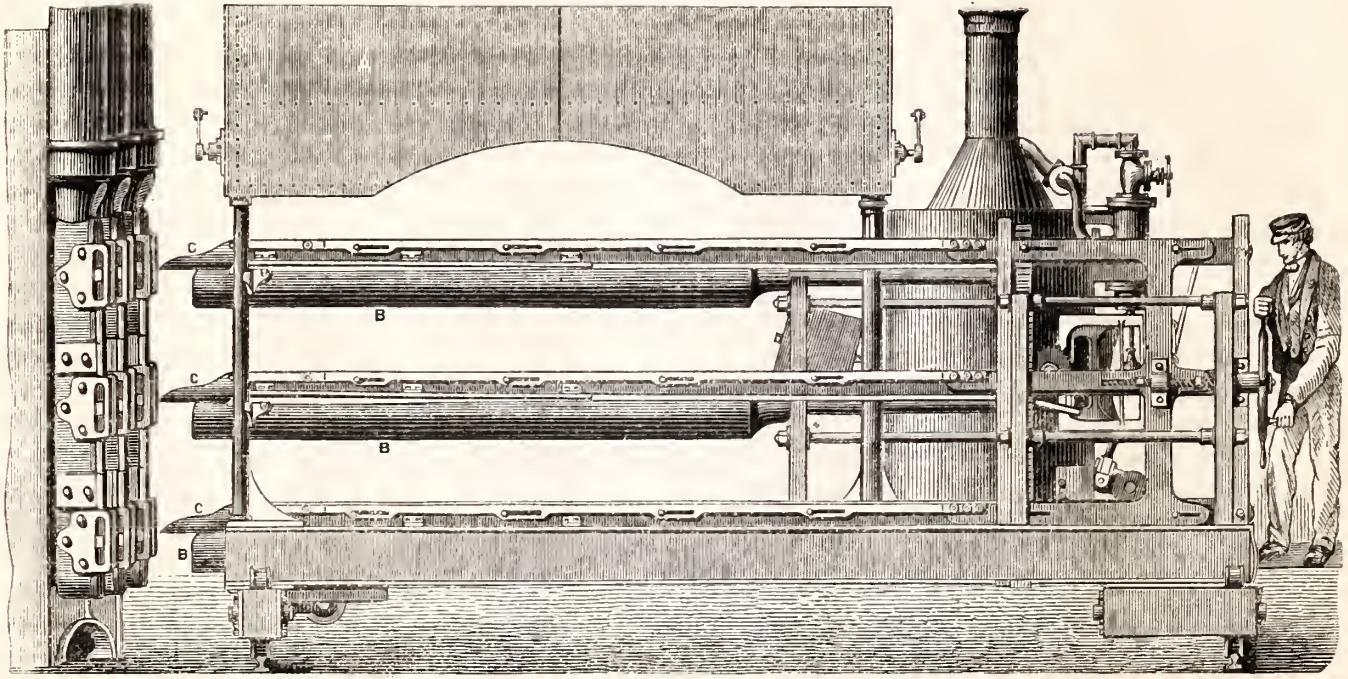
	No. 1	2	3	4	5	6	6	6	7	8
						2ft. 8in. wd.	3ft. 6in. wd.	4ft. wide		
Hearth	£27 0 0	5 0 0	15 0 0	29 0 0	17 0 0	14 0 0	16 10 0	19 0 0	16 10 0	13 0 0
Price of Stand Pipe	....	1 7 6	1 12 0	1 12 0	1 12 0	1 12 0	1 12 0	1 12 0	1 12 0	1 7 6
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Weight of Hearths	30	5	23	42	20	17	20	23	19	14
Weight of Bricks	....	....	....	....	5	4	6	7	7	6

MACHINE FOR DRAWING AND CHARGING GAS RETORTS.

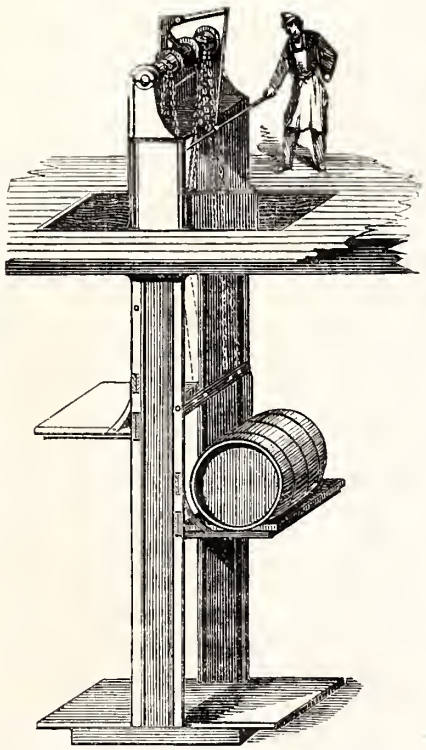
THIS is an ingenious machine lately invented and patented by Messrs. Holden & Best, and manufactured by Andw Handyside & Co., for charging and drawing gas retorts, and thus rendering unnecessary the great expense and severe exertion attending the ordinary process by manual labour.

The first machines were tried with great success at the Chartered Gas Works, London, and at one of the Gas Works of Paris; and three of the machines have been recently manufactured and set to work by Andw. Handyside & Co. at the Alliance Gas Works, Dublin. The apparatus is supported on a wrought-iron carriage, constructed to run on rails in front of the retorts, the whole length of the retort house. At one end of the carriage is fixed a pair of vertical high pressure engines, which work the whole of the machinery. The hopper or meter A contains the coal sufficient for two benches, and by means of shoots (not shown in the engraving) the coal can at will be transmitted to the three scoops B B B. By the aid of suitable gearing these scoops are propelled to the extremities of the retorts, where by a self-acting motion they turn over, and deposit their contents evenly from end to end of the retort, the scoops being then rapidly withdrawn. For drawing the charges the rakes are thrust forward into the retorts, and when at the extreme end the flaps C C C, till then horizontal, are brought into a vertical position, and draw with them, as the rakes recede, the whole contents of the retorts. The machine then advances along the house, alternately charging and drawing as required. By this apparatus eighteen retorts can be drawn and charged in twenty minutes, the time thus saved being of great value.

One bench containing nine retorts 20 feet long, having eighteen mouths fitted with patent doors and frames up to the ascension pipe, costs about £120. A drawing and charging machine complete, with steam engine, costs about £800. Thirty benches as above, with two machines and sixteen men, will carbonize 2,000 tons of coal per week of seven days. Andw. Handyside & Co. will, when desired, arrange with the patentees for the Royalty, which is not included in the prices just named.



MACHINE FOR DRAWING AND CHARGING GAS RETORTS.



HOISTS.

THERE are many different methods of applying power to lifts or hoists. The engraving shows one of several barrel hoists erected by Andw. Handyside & Co. at Messrs. Bass's Brewery, Burton-on-Trent. In this case the apparatus is worked by the ordinary shafting from the engine. A hoist of this kind can be used for lifting any kind of goods any height, and a descending and ascending load can be taken at the same time.

In places where there is no shafting and gearing, and where the steam power is at a considerable distance from the hoist, the necessary force can be effectually conveyed by water in a pipe underground. Wherever there is a steam boiler, and a certain simple apparatus in connection with it, the power can be transmitted to a hoist several hundred yards distant. Andw. Handyside & Co. have had a hoist of this kind in successful operation at the Britannia Iron Works for many years.

TANKS.

TANKS are made of both wrought and cast iron, but the latter material is superior in almost all cases, and is best adapted for resisting the action of the water. Cast-iron tanks are formed of plates, which are of moderate size and weight, and therefore well suited for exportation. Beyond 10 feet in depth wrought-iron tanks are generally preferred, as being best able to resist the outward pressure of a deep column of water. Andw. Handyside & Co. manufacture both kinds.

The following prices are for rectangular cast-iron tanks, and include strengthening stays, bolts, cement, caulking tools, and everything necessary to put the tanks together in place. Each tank is fitted together in the workshop, and properly marked for re-erection afterwards.

Cast-iron tanks are not suitable for hot water. If fixed above the ground level, the tanks may be supported on walls or timber, but iron girders are generally used for this purpose. Separate prices are therefore given for girders strong enough to carry the tanks. Of course the girders themselves have to be supported on walls or columns, as may be convenient in each case. Tanks of circular or irregular shape cost rather more than the ordinary kind.

Cast-iron Tanks.

	1,000 gals.	2,000 gals.	5,000 gals.	10,000 gals	20,000 gals.	30,000 gals.	50,000 gals.	70,000 gals.	100,000 gals.
Cast-iron Tanks, complete	£ 24 0 0	£ 40 0 0	£ 72 0 0	£ 128 0 0	£ 205 0 0	£ 261 0 0	£ 426 0 0	£ 572 0 0	£ 760 0 0
Width of each side	6 ft. × 6 ft.	9 ft. × 9 ft.	12 ft. × 12 ft.	17 ft. × 17 ft.	24 ft. × 24 ft.	24 ft. × 24 ft.	32 ft. × 32 ft.	36 ft. × 36 ft.	41 ft. × 41 ft.
Depth	4 ft. 9 in.	4 ft. 3 in.	6 feet	6 feet	6 feet	8 feet	8 feet	9 feet	10 feet
Weight	2 tons	3½ tons	6 tons	10½ tons	17½ tons	21½ tons	36¾ tons	47½ tons	63½ tons
Girders extra..... £	2 8 0	4 19 0	14 6 0	42 10 0	159 0 0	195 0 0	288 0 0	Price and Weight according to arrangement.	
Weight of Girders	4 cwt.	9 cwt.	1 ton 6 cwt.	4 tons 5 cwt.	15 tns. 18 cwt	19 tns. 10 cwt	32 tons		

THE FOUNDRY.

THIS forms an important part of the Britannia Iron Works, which have enjoyed a high reputation for castings for fifty years. This reputation has been acquired by the careful use of the best materials, and the adoption of many practical improvements in manufacture.

The foundry is well supplied with cranes and with large pits and other requisites for heavy castings; an extensive assortment of models is also kept. Generally, however, new work requires new models; and very careful attention is given to the production of these, a large number of skilled workmen being always employed in preparing them. This is a very important part of an iron-founder's business, and upon the attention given to it the finish of the castings very much depends.

ENGINE AND MACHINE CASTINGS.

THE qualities mainly requisite in these are closeness and toughness of texture and sharpness in outline, and are easily obtainable at Derby, because the iron produced in the county, especially when mixed with hematite iron and Scotch iron in proper proportions, supplies a material second to none in England; while the moulding sand obtained at the distance of a few miles is of such high reputation as to be sent in large quantities to the most distant parts of the kingdom. It may be mentioned as a matter sometimes of consequence to engineers in obtaining castings, that cylinders can be bored up to 8 feet diameter, and fly wheels turned and bored. The various machines described in other parts of this book will, however, best indicate the castings of this class, which are being regularly produced. Reference, however, should perhaps be made here to steam cylinders and hydraulic cylinders. These castings require special attention to many details in manufacture, and in the selection of the proper mixtures of material. Without this, soundness of texture (which is essential) cannot be secured, and it is almost needless to remark that only long experience, such as has been gained at the Britannia Iron Works in the production of this kind

of work, can fully ensure the desired result. Among the larger class of engineers' castings made at these works may be enumerated—screw piles, cylinders for bridge piers, and the heavier parts of land and marine engines. Castings can be made up to 30 tons in weight.

RAILWAY CARRIAGE CASTINGS.

AXLE boxes, buffer blocks, name plates, and other castings, needed in the manufacture of railway trucks and carriages, are made by And^{w}. Handyside & Co. in large numbers, and workmen are constantly employed in this special work for some of the principal railway carriage builders in the kingdom. There is great variety in the design and shape of axle boxes, and they cost generally from 8s. to 10s. per cwt. They can be fitted and supplied complete, with brass bearings.

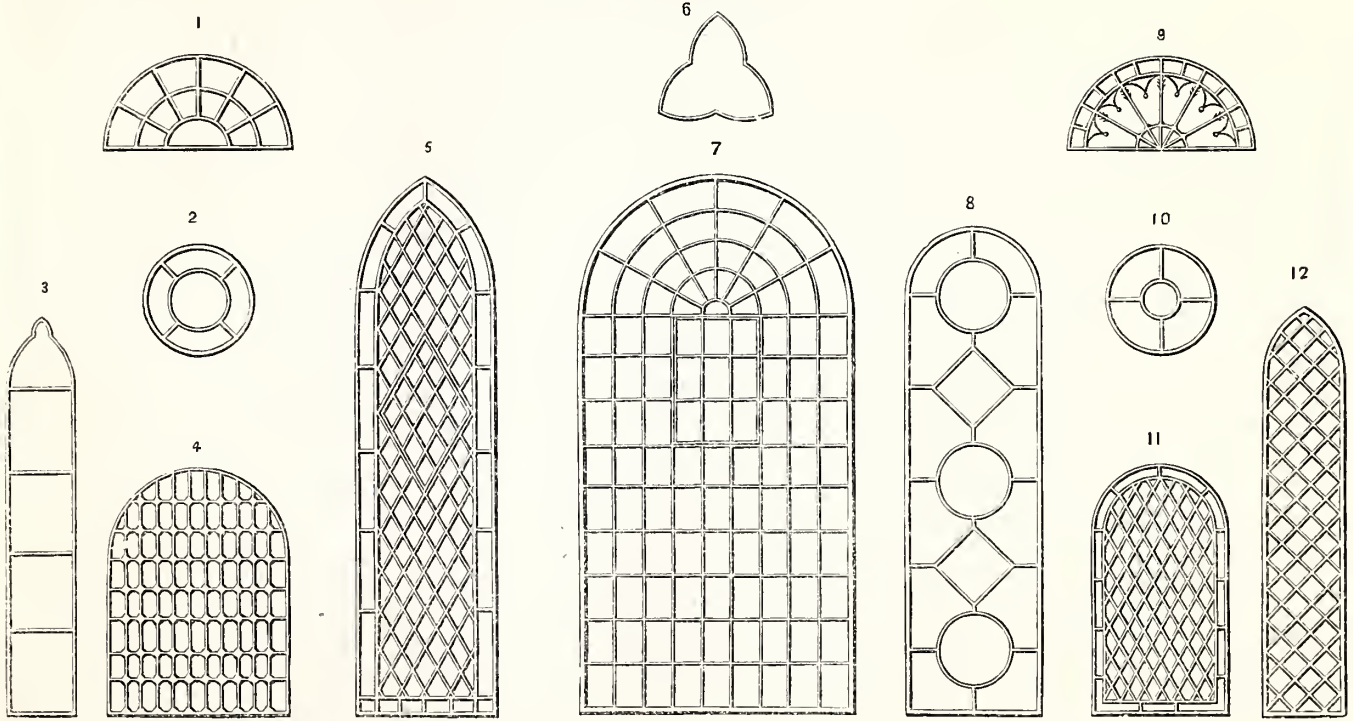
BUILDERS' CASTINGS.

UNDER this heading must be classed all castings used either in the framework of buildings, or in their decoration. The first are generally simple in form, but too often insufficient attention is given to the sections adopted. Money may often be saved and greater safety attained by the adoption of sections so contrived as to ensure the equal crystallization of the iron in cooling, and by the use of material of such quality as to permit the use of lighter sections. The practice of regarding the lowest price per ton as the most eligible, without reference to these considerations, is a mistake in economy as well as in mechanics. The portico in front of Broad Street Station, London, affords a specimen of the more ornamental class of builders' work. It is 180 feet long, and was made and erected by And^{w}. Handyside & Co. in 1865. The roof over the station is described at page 36. The large experience And^{w}. Handyside & Co. have had in this department of casting may be gathered from the various works illustrated and described in other parts of this book.

The engraving on the opposite page illustrates a few varieties of cast-iron windows. Of these about 1,500 models are carefully preserved and registered, and it is obvious that where a selection may be made from so large a

IRON WINDOWS.

Scale 1 2 3 4 5 6 of Feet



stock, a good deal of model-making and consequent expense may be saved. The engraving on preceding page shows examples of a few iron windows suitable for schools, factories, and prisons. The iron window admits of having portions made to open in various ways. The opening portion may be made of a lozenge, rectangular, or circular shape, hung upon pivots at the top, centre, or bottom, and opened and closed by lines and pulleys, or by levers worked by the hand, or, if out of easy reach, by gearing. For dwelling-houses and schools the casements are more often made to open upon hinges at the sides, and are closed by an ornamental iron buckle. The price of iron windows varies from about 9d. to 1s. 3d. per superficial foot, or if sold by weight, from 10s. to 16s. per cwt. The simpler kinds of opening casements add about 5s. to 7s. to the cost of each window.

London examples of the heavier class of windows may be seen in those of the Gutta Percha Co.'s Works, City Basin, and of the lighter and more ornamental in St. Olave's Schools, Southwark.

It is not easy to give definite quotations for castings of various classes, as, independently of the variation caused by cost of raw material, the price must obviously depend very much upon the number required. And^{w}. Handyside & Co. are prepared at all times to offer estimates based on the information supplied to them, and the more full and detailed such information is, the lower, as a rule, will the estimate be. They have never had any difficulty in competing where the quality of work is held to be of any consideration.

BRASS FOUNDRY.

AT the Britannia Iron Works there is a separate foundry for the manufacture of brass castings, and these can be made of any size up to 30 cwt. For the smaller castings the metal is melted in crucibles, but where more than 100 lbs. is wanted at once, it is found convenient to use a large furnace. In the working parts of engines and machinery, the durability of the bearings depends chiefly on the quality of the metal, and very slight differences in the alloy will greatly affect the character of the brass. And^{w}. Handyside & Co. make considerable quantities of the

larger kind of castings, such as air pump valves and buckets, linings for hydraulic cylinders, and coverings for the rams. In breweries and other places where water is required free from the taint of iron, brass pumps are almost invariably used, and of course cost considerably more than those made of iron. For small wheels and parts of a machine where great toughness is needed, brass is often used. Brass is sometimes also used for machines exposed to wet or damp, where iron would be liable to oxidation.

Many different mixtures have been composed for withstanding friction, and some of these may be preferred to the ordinary brass and gun-metal. And^{w}. Handyside & Co. will, if required, make castings of this kind according to proportions supplied to them.

ORNAMENTAL IRONWORK.

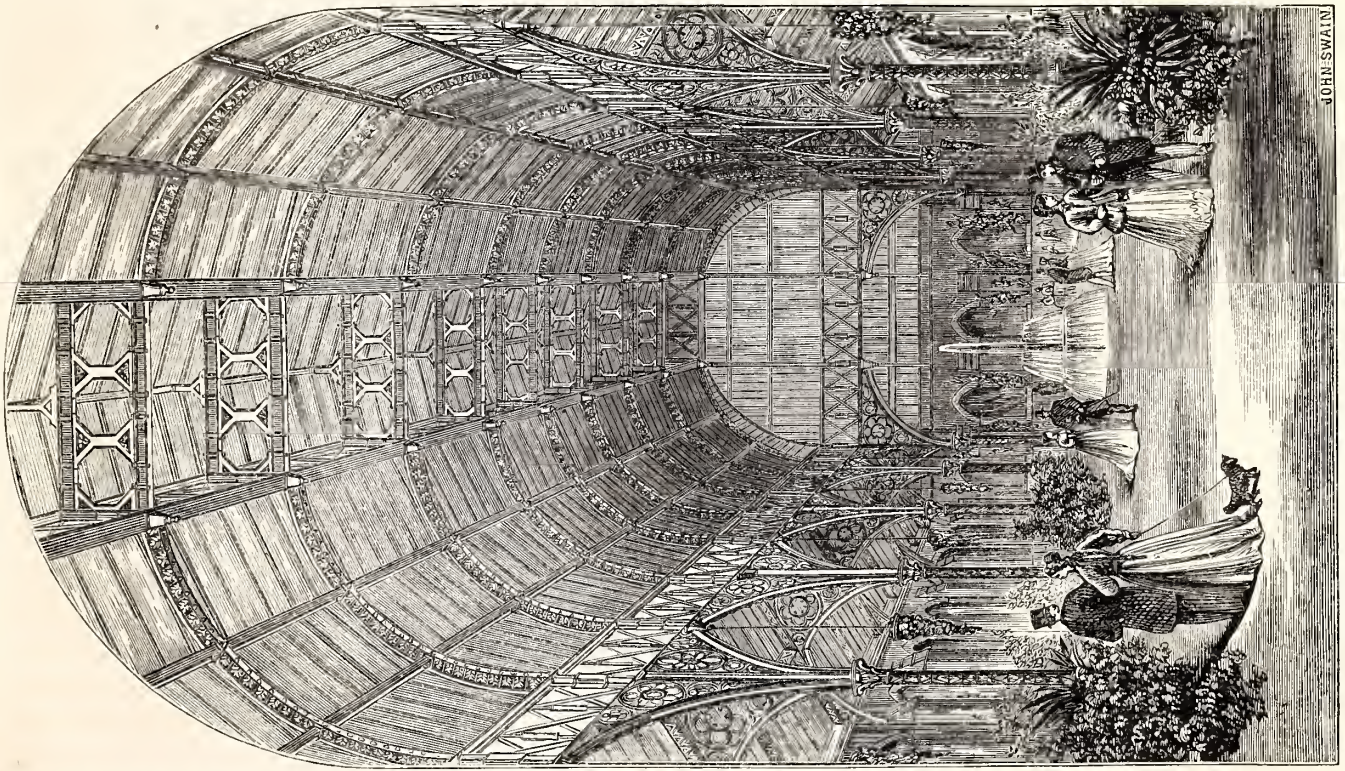
THIS department of work has always received very great attention at the Britannia Iron Works, and therefore it will be found to occupy a prominent place among the illustrations of this book. Cast iron is a material so easy of adaptation for ornamental purposes, that it is remarkable that its employment in this way on anything like a large scale is of such recent date. The great improvements in design which have of late years been shown in so many branches of manufacture have been but slowly extended in the use of cast iron. This doubtless arises mainly from the fact that it is but recently that architects have to any large extent recognised its use in ornamental forms. Even now many are hardly aware of how much can be done with it. The quality and the rude appearance of many of the castings supplied to builders in this country have without doubt created considerable prejudice among architects, and have prevented the use of iron in many kinds of work where artistic ornament is desired, and where if properly manufactured iron could be adopted to great advantage. As a material for structural purposes, *good* cast iron is invaluable; and if, while maintaining the forms natural to it, ornament can also be given, an important result is gained. Many architects are perhaps unaware how much the mere quality of the iron, apart from the skill in its after-treatment, affects the success of an attempt to use it with taste. Of the immense differences in point of *strength*, enough has been said at the commencement of this book, under the head of "Quality of Iron," but while the use of good material permits lightness of form to be combined with safety, it also affords a wide scope for artistic treatment. Many of the designs usually deemed to be only possible in hammered iron, a greatly more expensive and less durable material, are obtainable in cast iron with equal delicacy and effect. The foliage upon the capitals of columns may be taken as an apt example. Although hammered wrought iron is often used for this purpose, the cost is so great as to preclude its use in most instances, and this form of iron is also ill adapted to resist the

CAST-IRON CAPITALS FOR COLUMNS.

action of the weather. With good tough cast iron skilfully treated, ornament may be produced which gives with fidelity the design of the architect at a moderate cost. All the crispness and delicacy of outline, the relief and "undercut," which are essential to effect, can be perfectly secured. Andw. Handyside & Co. have had long and varied experience in works of this kind, and are assisted by workmen engaged solely in them. What can be done in this way may be seen in many of the works referred to in this book. The engraving on preceding page shows some foliated capitals made entirely in cast iron. The large one on the right of the page represents one of the columns in the Leeds Winter Garden which is shown on the opposite page.

CONSERVATORIES.

CONSERVATORIES and other cast-iron buildings of the same class form the first and largest department of ornamental ironwork illustrated in the following pages. Considerable impulse was given to the manufacture of buildings of this kind by the successful erection of the large Exhibition Palace in 1851 in Hyde Park, but for some years before that time Andw. Handyside & Co. had constructed conservatories mainly of iron and glass for noblemen and gentlemen in different parts of the country. Cast iron is particularly adapted for such work, and the slight columns and elegant arched spandrils obtained in this material afford great scope for ornamental design. The Conservatory in the gardens of the Royal Horticultural Society at South Kensington is the largest work of its kind yet constructed by Andw. Handyside & Co. It was made by them in 1860, from the designs of the late Capt. Fowke, R.E., and is probably one of the largest and finest conservatories in the world. It is 265 feet long, 96 feet wide, and 75 feet high in the central aisle. Its framework is of cast iron, and the roof of wrought iron, the main semi-circular ribs of the latter being pierced. The building is remarkable for the extreme lightness of its construction, and the very simplicity of its outline offers manifest opportunities to the gardener for decoration by means of climbing and trailing plants. The total weight of iron is 226 tons. The cost of the ironwork of such a building (without erection) would be about £3,600.



JOHN SWAIN

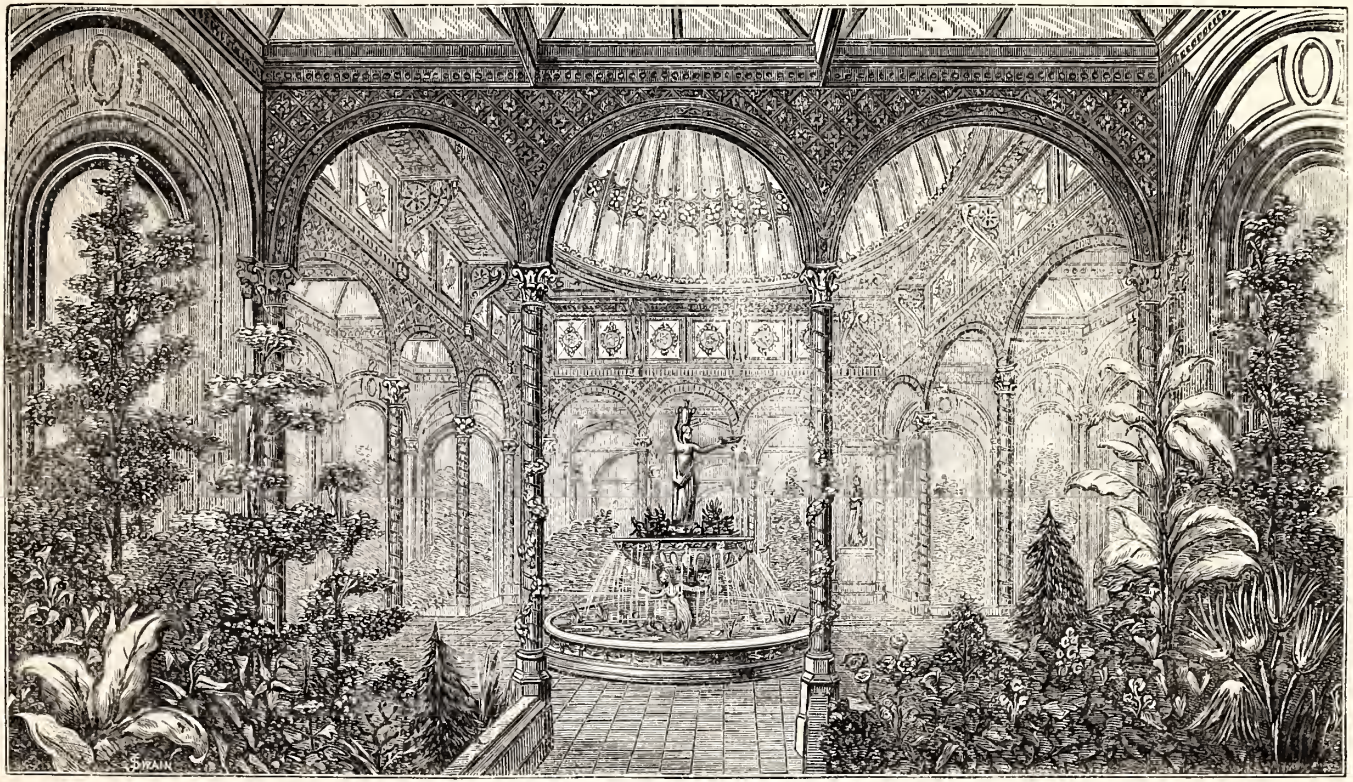
WINTER GARDEN IN THE NEW INFIRMARY, LEEDS.

N 2

On the preceding page is shown the Winter Garden occupying the central quadrangle of the new Infirmary at Leeds. It was made and erected by Andw. Handyside & Co. from the designs of Mr. George Gilbert Scott, R.A., and was first used for the Leeds Art Exhibition, opened by the Prince of Wales. It is, with exception of the lattice girders over the columns and in the clerestory, entirely of cast iron. It is 151 feet long, 63 feet wide, and 60 feet high. The construction of this building is peculiar, involving no "thrust" upon the walls; the main roof, which is really carried by the four corner rafters, having its thrust taken by the parallelogram of lattice girders connecting the heads of the twelve columns. The weight of ironwork is about 150 tons. The sash frames for glazing are of wood. The framework of such a building as this, including the wooden sky-light bars, delivered ready for erection anywhere in Great Britain, would cost about £3,000.

The conservatory shown on the opposite page has lately been erected by Andw. Handyside & Co., near London, for Henry Bessemer, Esq., from the design of Messrs. Banks & Barry, Architects. This is one of the most elaborately ornamental iron buildings yet constructed, and with the exception of the ribs in the dome is entirely of cast iron. The conservatory is rectangular, and from the square framework a circular dome rises to a height of 40 feet. The columns are light and elegant, with ornamental capitals, and the arches, brackets, and other main parts of the structure are of light pierced work. A building of this kind affords great scope for colour decoration.

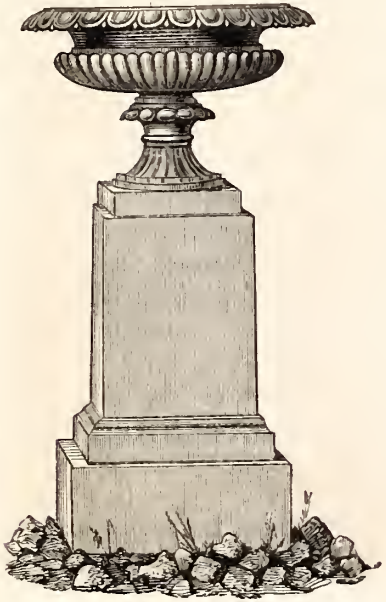
The Kiosk shown in the illustration on page 95 is rather a remarkable specimen of ironwork, constructed by Andw. Handyside & Co., from the designs of Mr. Owen Jones and Mr. R. M. Ordish. The building is 80 feet long, 40 feet wide, and 42 feet high in the centre. The columns are double, and are bolted upon bed-plates which extend 10 feet into the building under the floor, and thus present sufficient resistance to the strain transmitted from the roof through the columns. The roof ribs spring diagonally from each column, and by their intersection divide the entire roof into equal squares, thus giving the hipped ends of the building the same appearance as the rest of the roof. This peculiar construction renders the same models applicable to any greater length, advancing by 10 feet. The details



CONSERVATORY NEAR LONDON.

show an entirely novel application of cast iron, the intersecting ribs being dove-tailed together in an ingenious manner, the use of bolts, except in a very few instances, being thus avoided.

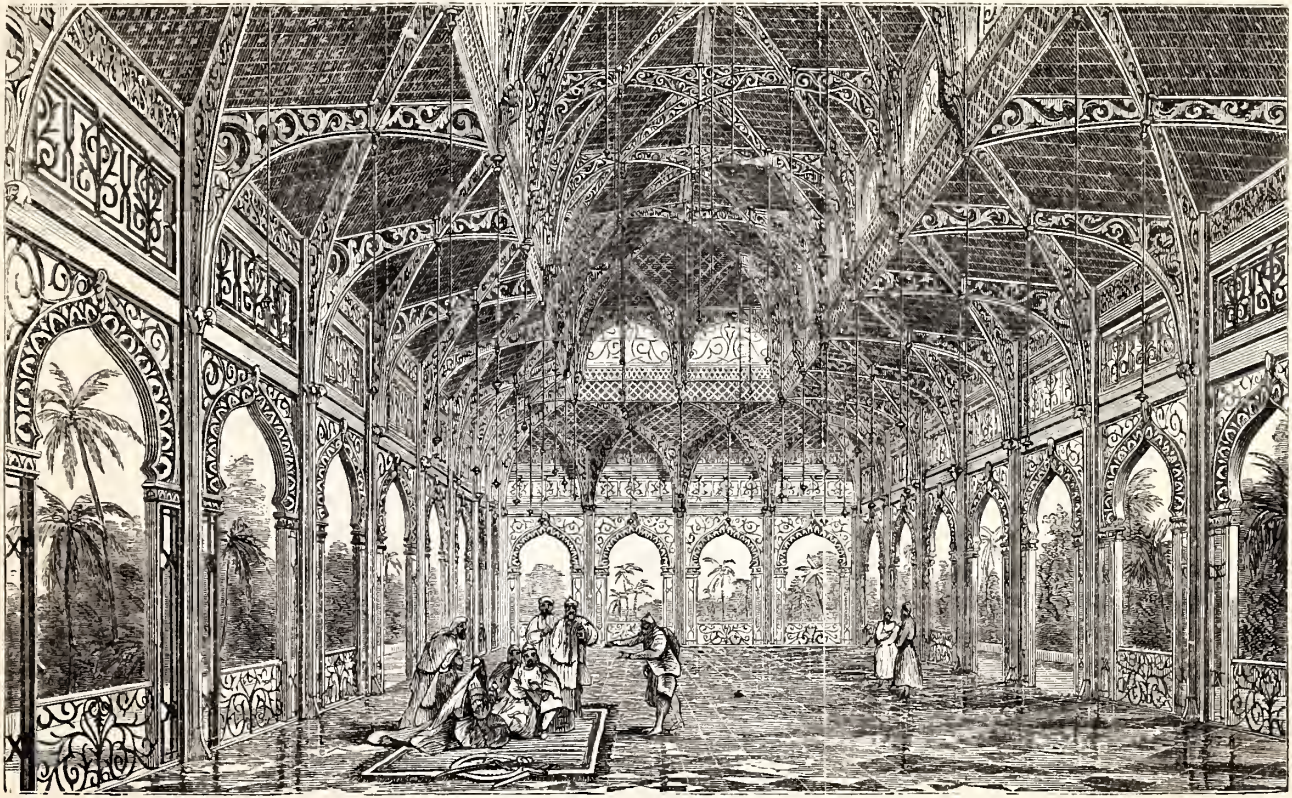
The building is entirely of cast iron, of which there is about 200 tons. The cost of such a building delivered at any English port, ready for erection abroad, would be about £2,800. As this only includes the iron framework, the material for roof covering and floor would cost an additional sum.



CAST-IRON VASES AND FOUNTAINS.

THE Britannia Iron Works have long been well known for the production of these articles, so useful and effective in garden decoration. The use of cast iron permits a delicacy of outline which is impossible in cheap stone or terra-cotta, and the fine moulding sand obtained at Derby allows a smoothness of surface otherwise unattainable. Cast-iron vases, if occasionally painted, are imperishable, and will not crack when exposed to wet or frosty weather. Each vase has an aperture at the base to let off the water.

Amongst the best forms of vases are those which are oldest, and which reproduce with fidelity the most famous classical designs. The Tazza vase shown on this page is made in sizes from 1 foot 3 ins. to 2 feet 6 ins. in diameter, costing from £1 to £3 5s. each. A fac-simile of the Warwick vase is made; the heads cast upon it are in deep relief, and it is a handsome and remarkable casting. It is 2 feet in diameter, and costs £6. A large vase was designed especially for the London Exhibition of 1862, and obtained a prize medal. Its main features are the "Night" and "Morning" groups of Thorwaldsen, which adorn the opposite sides of the vase, and the sharp and



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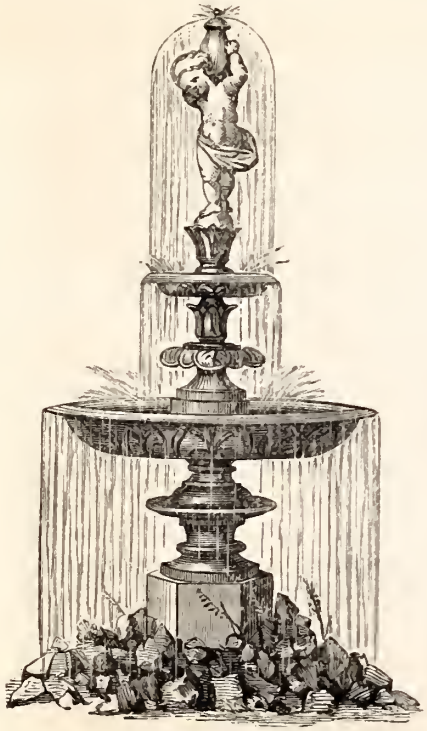


cleanly cast foliage which forms the handles. The vase stands 4 feet 9 ins. high, without the pedestal, and costs £18.

A copy in iron of the famous Medici vase is also made. It is 1 foot 11 ins. in diameter, and costs £3 10s. A smaller size, 15½ ins. in diameter, is made for £2, and both sizes are made without the figures for a lower price. The small vase on page 97 is 18 ins. high.

It is impossible to enumerate here all the different designs of vases, of which engravings could be supplied, but they are generally elegant and effective, and the prices vary from £1 to £20. The vases are supplied with or without pedestals, which cost from 10s. to £5 extra.

Handsome fountains can be produced in iron at a much less cost than in stone; and the finest ornamental work in cast iron will endure exposure to the wet without deterioration. And^{w}. Handyside & Co. have for many years manufactured iron fountains, and for these also are careful to choose good designs, which can be faithfully rendered. Small fountains in which the stem and jet spring from a vase, are made at from £2 and upwards, and at from £5 upwards there is a choice of elegant designs. In some cases a succession of basins terminate in a stem; in others figures form the prominent feature of the design. The fountain in the engraving on this page is 5 feet 4 ins. high, and costs £8. Large fountains, suitable for market places and other public situations, cost from £40 to £80, and drinking fountains from £5 to £15; and And^{w}. Handyside & Co. will undertake to

make fountains of any size from original designs. A large variety of jets are made which throw the water in different ways. One jet is supplied with each fountain, and additional ones cost from 4s. to 30s.

Lithographed sheets of the different designs made by And^{w} Handyside & Co. are supplied, and these show about forty different sizes and shapes of vases, and thirty of fountains.

LAMP PILLARS.

THE engraving on page 99 shows a few varieties of lamp pillars made by And^{w} Handyside & Co.

The cheapest kinds of lamp pillars used in the public streets are often of a very rude form, and are made of inferior iron, but there is a growing demand, however, for designs of a better character, and the difference in cost is slight. Lamp pillars of the simpler kind are made from 10 feet to 12 feet in height, and cost from £1 15s. to £4. Nos. 1 and 4 in the engraving cost £3 each. They are 10 feet 6 ins. high, in addition to the base for fixing underground, and each weighs about 4 cwt. No. 2 is a handsome pillar, having the shaft carved in relief. The octagonal base is arranged as a drinking fountain, and four of the eight sides have basins and lion's head taps. In the square base below are two dog troughs, into which the water flows from the upper basins. This pillar complete costs £17, and weighs about 8 cwt. If arranged for three lamps, the cost is £18 10s. The same pillar and base, but with no provision for drinking fountain and dog trough, costs £13. A very handsome but shorter pillar is made from the same pattern, by omitting altogether the octagonal base, and reducing the height to 9 feet 3 ins. The pillar is then well adapted for lobbies and staircases, or for standing on a stone pedestal, and its cost is reduced to £6 15s., and its weight to 4 cwt. A lithographic engraving showing the pillar more plainly and to a larger scale, can be furnished if required.

No. 3 is a large and handsome pillar, adapted for the centre of an open space, or wherever three or five lamps are required. It is 14 feet high, besides the usual base underground, and costs £9.

No. 5 has the same shaft as No. 2, but the base consists of the No. 2 letter box, illustrated on page 101. It costs £23 complete, with all the letter box fittings.

All the pillars described here are well made, but it is not possible in an engraving to so small a scale to represent the ornamental detail. Designs and estimates can be supplied for special cases; and wherever a considerable number of pillars is required, the cost of a new pattern adds but slightly to the expense. The prices that have been given do not include the cost of lamps. These can be supplied with the pillars at a cost of from 25s. to 80s. each.

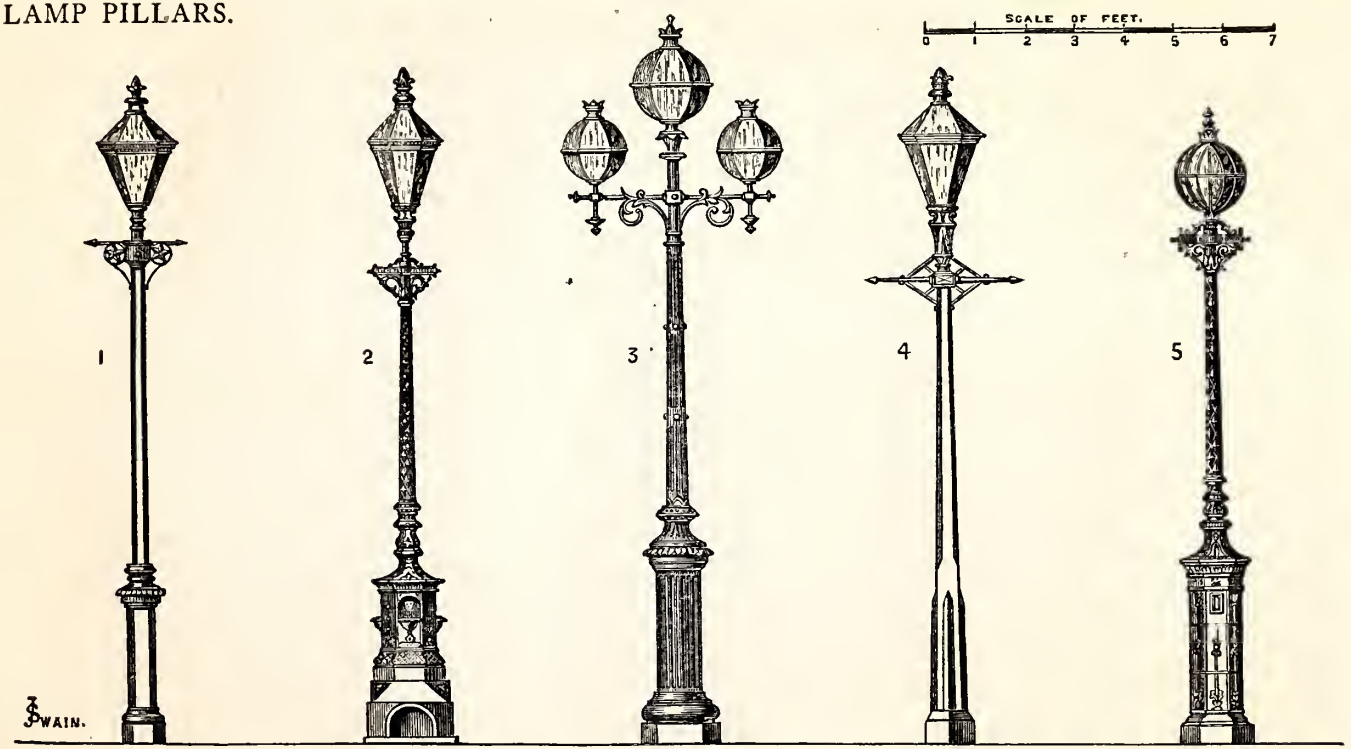
PILLAR LETTER BOXES.

THE illustration on page 101 shows a few varieties of pillar letter boxes, or street post offices. The use of these in the public streets is becoming every day more general, and they have been manufactured by And^{w}. Handyside & Co. in large numbers. Each pillar is about 5 feet high, and 16 ins. diameter, and has a base (not shown in engraving) 2 feet long, for fixing in the ground.

No. 1 is octagonal, and simple in design, and costs £7 10s. No. 2 is octagonal, with rather more of ornament, and costs £9 10s. No. 3 is fluted, and costs £9 12s. The fittings included in these prices are in each case the same, and are such as have been supplied to, and approved by, the Postmaster General. They consist of a canvass bag on frame, and an opening flap, with balance weight. The middle panel of each pillar opens as a door, and is fitted with a good brass lever lock having two keys. The prices named include such ordinary inscriptions as "Letter Box," "Post Office," and a crown, &c., cast upon the pillar. Any special or local crest or inscription can be made for a slight additional cost. The pillars weigh from 6 cwt. to 7 cwt. each.

An elegant lamp pillar, with an octagonal letter box as a base, is shown in fig. 5, on page 99.

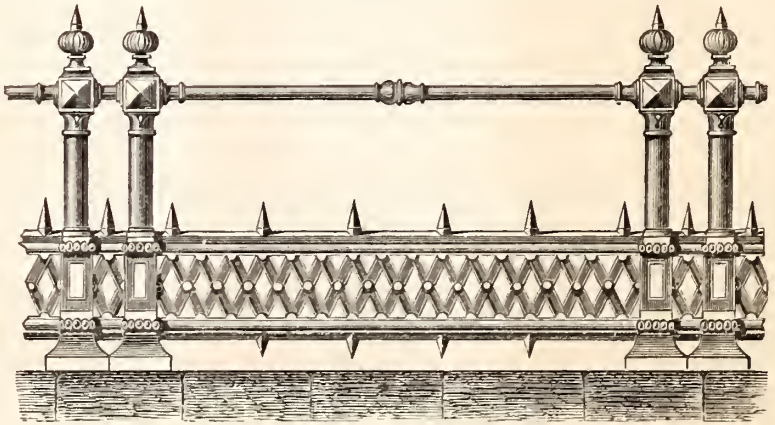
LAMP PILLARS.

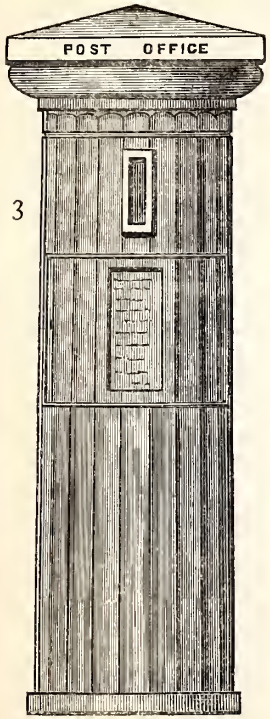


GATES AND RAILINGS.

RAILINGS and Gates are made of either wrought or cast iron, or of the two combined. Wrought iron is generally used for some of the horizontal bars and other parts where strength is needed without great size. Wrought iron, too, is often employed where very light and elaborate ornament is required, and designs of great beauty are formed in this material; cast iron, however, is oftenest used. And^{w}. Handyside & Co. construct railings and gates for every variety of purpose. It would require too much space to illustrate the different patterns which they have in stock, but they will at any time supply sketches to suit particular cases.

For railing which may be subjected to rough usage, or which is liable to damage by shipment or otherwise, And^{w}. Handyside & Co. use strong wrought-iron tubes, the ornamental portion being of cast iron neatly attached.





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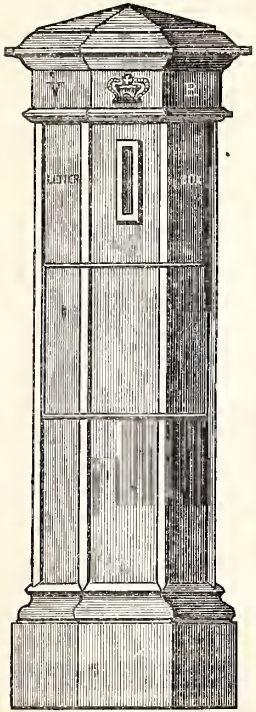

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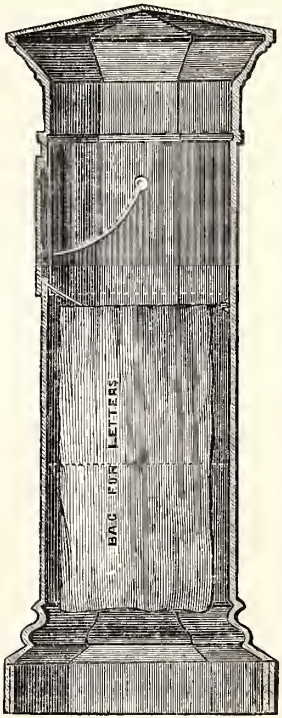

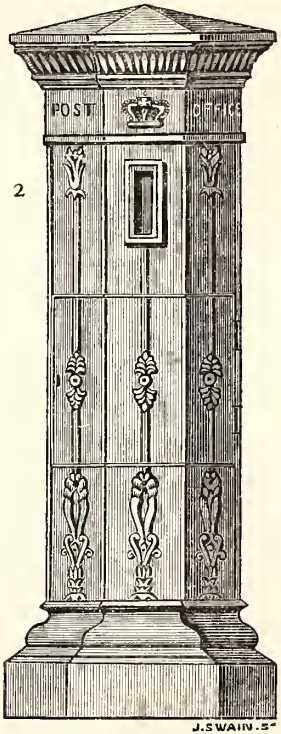

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J.S WAIN. Sc

PILLAR LETTER BOXES.

Very graceful designs may be rendered in cast iron, and the remarks on page 88 about this material apply here also. As an example of light cast-iron railing, the sketch on left of the engraving on page 100 shows a panel of a balcony constructed by Andw. Handyside & Co. for the Countess of Waldegrave at Strawberry Hill. By the careful use of iron of proper tenacity, sufficient strength is attained; and one model having been made, a considerable length of railing can be constructed at a far less cost than would have been possible in hammered wrought iron. The other illustration shows a railing 3 feet high, cast by Andw. Handyside & Co. for the front of certain London mansions.

ENGLISH MEASURES AND THE FRENCH DECIMAL SYSTEM.

LONG MEASURE.

English.

12 Inches.....=1 Foot
3 Feet.....=1 Yard
1760 Yards.....=1 Mile

English.		*French.*
1 Inch	=	.0254 METRES
39.37 Inches	=	1 ,,
1 Foot	=	.30479 ,,
1 Yard	=	.91437 ,,
1 Mile	=	1609.31 ,,

WEIGHTS.

English (Avoirdupois Weight).

16 Ounces (oz.)=1 Pound (lb.)
28 lbs.....=1 Quarter
4 Quarters...=1 Hundredweight (cwt.)
20 cwt.....=1 Ton

English.		*French.*
3.527 oz.	=	1 Hectogramme
2.2048 lbs.	=	1 Kilogramme
.01969 cwt.	=	1 ,,
1 Ton	=	1015.965 ,,
1 ,,	=	1.016 Ton French

SQUARE MEASURE.

English.

144 Square Inches =1 Square Foot
9 Square Feet...=1 Square Yard
100 ,, ...=1 Square of Roofing
4840 Square Yards =1 Acre

English.		*French.*
155 Square Inches	=	1 Milliare
10.764 Square Feet	=	1 Centiare
11.96 Square Yards	=	1 Deciare
119.6 ,,	=	1 ARE

WEIGHT OF IRON.

Cast Iron.

1 Cubic Inch .....weighs .263 lbs.
1 Cubic Foot ..... ,, 454.46 ,,
1 Square Foot, 1 in. thick ,, 37.87 ,,

Wrought Iron.

1 Cubic Inch .....weighs .279 lbs.
1 Cubic Foot ..... ,, 481.2 ,,
1 Square Foot, 1 in. thick ,, 40.1 ,,

SOLID MEASURE.

English.

1728 Cubic Inches ...=1 Cubic Foot
27 Cubic Feet.....=1 Cubic Yard
40 Cubic Feet.....=1 Ton of Shipping (freight)

English.		*French.*
61.028 Cubic Ins.	=	1 Millistere
610.28 ,,	=	1 Centistere
3.532 Cubic Ft.	=	1 Decistere
35.32 ,,	=	1 STERE (Cubic Metre)

DRY AND FLUID MEASURE.

English.

2 Pints .....=1 Quart
4 Quarts..... ..=1 Gallon
2 Gallons .....=1 Peck
4 Pecks .....=1 Bushel
1 Gallon.....=277.27 Cubic Inches
1 ,, ...= .16 Cubic Feet
1 Gallon of Distilled Water weighs 10 lbs.

English.		*French.*
1.761 Pints	=	1 LITRE
2.2 Gallons	=	1 Decalitre
2.75 Bushels	=	1 Hectolitre

THE FRENCH DECIMAL SYSTEM AND ENGLISH MEASURES.

LONG MEASURE.

French.

10 Millimetres .....= 1 Centimetre
10 Centimetres .....= 1 Decimetre
10 Decimetres.....= 1 METRE

French.		*English.*
1 Millimetre	=	0.0393 Inch
1 Centimetre.....	=	0.3937 ,,
1 Decimetre	=	3.9371 ,,
1 METRE	=	39.371 ,,
1609.31 ,, ...	=	1 Mile

WEIGHTS.

French.

10 Decigrammes .....= 1 GRAMME
10 GRAMMES .....= 1 Decagramme
10 Decagrammes .....= 1 Hectogramme
10 Hectogrammes.....= 1 Kilogramme

French.		*English.*
1 GRAMME	=	.0022 lbs.
.4535 Kilogrammes ...	=	1 ,,
50.787 ,, ...	=	1 cwt.
1015.965 ,, ...	=	1 Ton.

SQUARE MEASURE.

French.

10 Milliares .....= 1 Centiare
10 Centiares .....= 1 Deciare
10 Deciares .....= 1 ARE
1 ARE .....= 100 Square Metres

French.		*English.*
1 Milliare ...	=	155 Square Inches
1 Centiare ...	=	10.764 Square Feet
1 Deciare ...	=	11.96 Square Yards
1 ARE	=	119.6 ,,
40.467 ,, ...	=	1 Acre

WEIGHT OF IRON.

Cast Iron.

1 Centistere weighs 160.5 lbs. English.

Wrought Iron.

1 Centistere weighs 170 lbs. English.

SOLID MEASURE.

French.

10 Millisteres.....= 1 Centistere
10 Centisteres .....= 1 Decistere
10 Desisteres .....= 1 STERE
1 STERE .....= a Cubic Metre

French.		*English.*
1 Centistere	=	610.28 Cubic Inches
1 Decistere	=	3.532 Cubic Feet
1 STERE	=	35.32 ,,

DRY AND FLUID MEASURE.

French.

10 Millilitres ... ...= 1 Centilitre
10 Centilitres .....= 1 Decilitre
10 Decilitres ... ..= 1 LITRE
1 LITRE .....= a Cubic Decimetre

French.		*English.*
1 LITRE	=	61.028 Cubic Inches
4.54 ,, ...	=	1 Gallon

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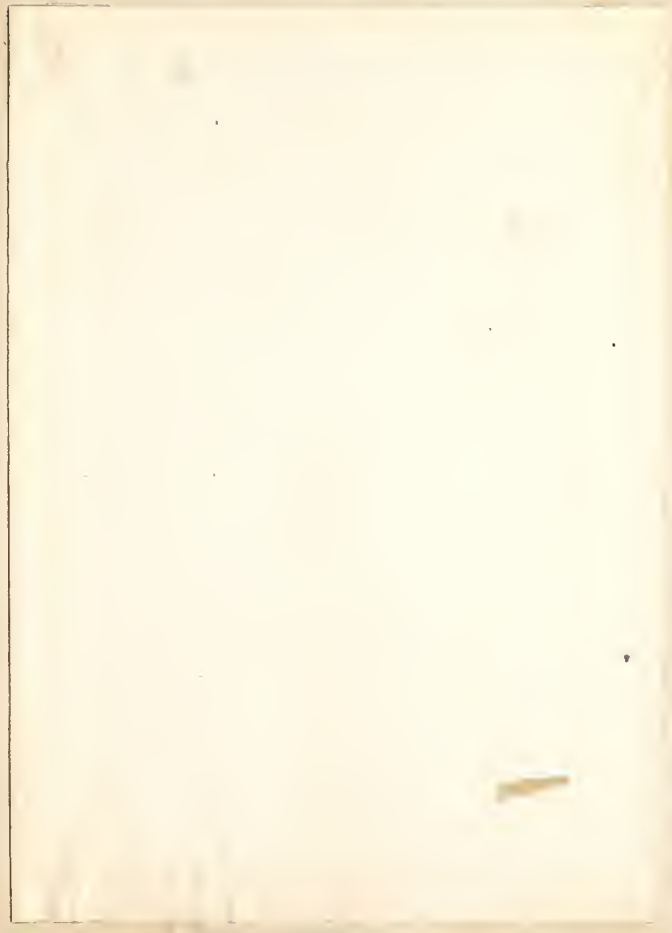
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